# Water Quality Review: Sierra Nevada 2008 Lake Monitoring

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## Executive Summary

Twenty-two Wilderness lakes were sampled for acid-base water chemistry and water transparency between June and September 2008 as part of Project LAKES, the Sierra Nevada long-term lake monitoring project of the Pacific Southwest Region, USDA Forest Service Air Resources Program. After incrementally increasing the number of lakes sampled each year since 2000, 2008 was the second year that the complete network of lakes was sampled in Class I Wilderness Areas in the Sierra Nevada, southern Cascades, and northeastern California overseen by the Pacific Southwest Region of the USDA Forest Service.

There is no current evidence suggesting either acidification or nutrient buildup in the lakes monitored in summer 2008. The lakes sampled largely retain the chemically dilute status that has been evident since 2002. An exception is Patterson Lake, in the South Warner Wilderness of northeastern California where lake chemistry and transparency have always

differed appreciably from lakes monitored in the Sierra Nevada. Different geologic and atmospheric conditions are the probable cause for these differences.

Eleven monitoring lakes have records of between 6 and 23 years in length, long enough for preliminary statistical analysis of temporal change. None of these lakes experienced a significant decline in the primary indicator for acidification, acid neutralizing capacity (ANC). Statistically significant changes were identified for all constituents, but the magnitude of most of the changes was low, usually below 0.10 $\mu Eq\ L^{-1}$ per year. Exceptions were increases in ANC (Powell Lake), calcium (Long Lake), and sodium (Patterson Lake) where the changes were almost 1.0 $\mu Eq\ L^{-1}$ per year. Among the minor changes, a decline in sulfate continued (in comparison to several earlier years) at Waca and Smith Lakes, both in Desolation Wilderness immediately west of Lake Tahoe. The long-term mean decline rates were 0.13 and 0.09 $\mu Eq\ L^{-1}$ per year at Waca and Smith respectively. Because these and other changes were minor, and the duration of records at many lakes is still short, these changes do not appear to warrant further assessment at this time. The full suite of changes is nevertheless detailed in a trailing section of this report.

The 2008 quality control analyses did not identify any new or unexpected issues, and for all QA/QC metrics the 2008 data are on par or better than in prior years. The single most notable QA/QC result is the shift in 2008 away from a persistent anion under-estimation through most prior years to an approximate equivalency of anion under-estimation to cation over-estimation in 2008.

Compared to 2007 and many prior years, many lakes experienced increases in two major chemical constituents, ANC and calcium. Reasons for these increases are unknown, but these changes are not a cause for concern. Nevertheless these changes are intriguing, and could suggest improved buffering capability on the regional scale, but a longer monitoring record is needed to substantiate this speculation. The 2008 ANC increases were insufficient to trigger a statistically significant change in ANC over the lifetime of the monitoring program.

Lake transparency (clarity) can be a good indicator of potential eutrophication. Although the record length is too short for statistical assessment of transparency change through time there is no current indication of transparency problems. Many monitored lakes are transparent to their bottoms and those that aren't have transparencies within the range documented in the 1985 Western Lake Survey for Sierra Nevada Wilderness lakes.

Two recommendations are to:

1) **Continue monitoring all lakes in the network.** The lake sampling is aimed at identifying human-caused changes in lakes in selected California Wildernesses. Because changes can be subtle several years are needed before supportable interpretations about trends in lake chemistry can be made. The network of long-term monitoring lakes is complete and project costs should drop because fewer lakes are now sampled than in prior years. Continued sampling is needed to determine if the chemistry of the Wilderness lakes is changing, and if so if atmospheric deposition is a cause of the changes. One-half of the lakes now have at best records minimally long enough to assess temporal change. Each year the duration of monitoring for each lake grows so that continued monitoring will allow better estimates of trends in more lakes each year.

2) **Continue, in refresher training for lake monitoring staff, to emphasize comprehensive quality control practices.** In the past a variety of issues have caused minor problems in the quality of the data. For instance mailing labels have had illegible zip codes and inconsistent labeling of sample containers has made their origin (e.g., shoreline or epilimnion) questionable. These are not mentioned to criticize field efforts but rather to point out a few of the many details that can "go wrong". Constant vigilance is needed in both field and laboratory activities to assure the collection of reliable information.

## 1.0 Introduction

**W**ilderness Areas are important national resources providing relatively unaltered natural landscapes for our enjoyment and as refugia for a variety of biota. Although watershed activities in Wildernesses are highly constrained, damage to some of these fragile resources is possible through short and long-range transport of air pollutants (Eilers 2003). For instance, Sickman et al. (2003) believe "…that lakes throughout the Sierra Nevada are experiencing measurable

eutrophication in response to the atmospheric deposition of nutrients" and Fenn et al. (2003) document elevated nitrate levels in high-elevation Sierran lakes, reportedly from nitrogen deposition. To address this concern, in 2000 the Air Resources Program of the Pacific Southwest Region (Region 5) of the USDA Forest Service (FS) initiated lake monitoring in Class I Wilderness Areas of the Sierra Nevada, California Cascades and northeastern California. A monitoring goal of this program is to provide early indication of possible impacts associated with deposition of acid-rain precursors.

This report assesses and interprets water chemistry data collected in 2008 and compares these data against information obtained in prior years. This report does not directly specify the background context for lake or stream monitoring by the regional Air Resources Program. One objective of the monitoring, however, is to address the management goal of maintaining or improving aquatic, physical and biological air quality related values (AQRVs) of "Class I" Wilderness Areas as mandated by amendments to the Clear Air Act and interpreted by the US Senate as an "affirmative responsibility by federal resource managers to err on the side of protecting AQRVs for future generations" (US Senate 1977).

## 2.0 Lake Monitoring Network

**O**ne intent of the Region 5 lake monitoring program is to follow the precedent of other FS regions by identifying a small number of lakes sensitive to atmospherically-driven acidification in each Class I Area and monitoring them over the long term. The premise is that monitoring lakes (operationally defined as water bodies greater than one hectare in area and greater than two meters in depth) particularly vulnerable to potential acidification will act as "a canary in a coal mine" and that their protection presupposes protection of less sensitive lakes.

ANC is the single best indicator of lake sensitivity to acidification (Sullivan et al. 2001). Lakes with low ANC are sensitive to acidification, and low-ANC lakes provide information relevant to possible nutrient issues. The selection process for long-term monitoring lakes (those with low ANC) is not simple and requires a combination of modeling (Berg et al. 2005) and synoptic sampling prior to final selection. Twenty-two monitoring lakes were sampled in 2008. These lakes were selected after a one-time synoptic sampling of many lakes in each Wilderness in which ANC and other chemical constituents were evaluated. 2008 is the second year that the complete network of lakes was sampled in a standardized manner. The network, including lakes in all Class I Wildernesses ranging from the Sierra National Forest in the southern Sierra Nevada (John Muir Wilderness) to the Modoc National Forest in the northeastern corner of California (South Warner Wilderness), is now complete and no other lakes are anticipated to be added (Figure 1) (Domeland Wilderness, the southern-most Class I Area in the Sierra Nevada, has no lakes and is not included in the sampling network.

In 2008 twenty-two lakes were sampled from eleven Wildernesses as follows:

| Wilderness | Number of Lakes Sampled | Long-term Monitoring Lakes |
|---|---|---|
| Hoover | 2 | Moat, Cascade |
| John Muir | 5 | E chain, Vermilion, Treasure, E Wahoo, Bench |
| Kaiser | 1 | Long |
| Ansel Adams | 3 | Walton, Little E Marie, Dana |
| Dinkey Lakes | 1 | Bullfrog |
| Mokelumne | 2 | Mokelumne 14, Lower Cole Ck |
| Desolation | 2 | Smith, Waca |
| Emigrant | 3 | Powell, Karls, Key |
| Caribou | 1 | Caribou 8 |
| 1000 Lakes | 1 | Hufford |
| South Warner | 1 | Patterson |

Outlet/shoreline, as well as mid-lake, samples were also collected at five of the lakes to provide information on the option to sample only outlets in the future.

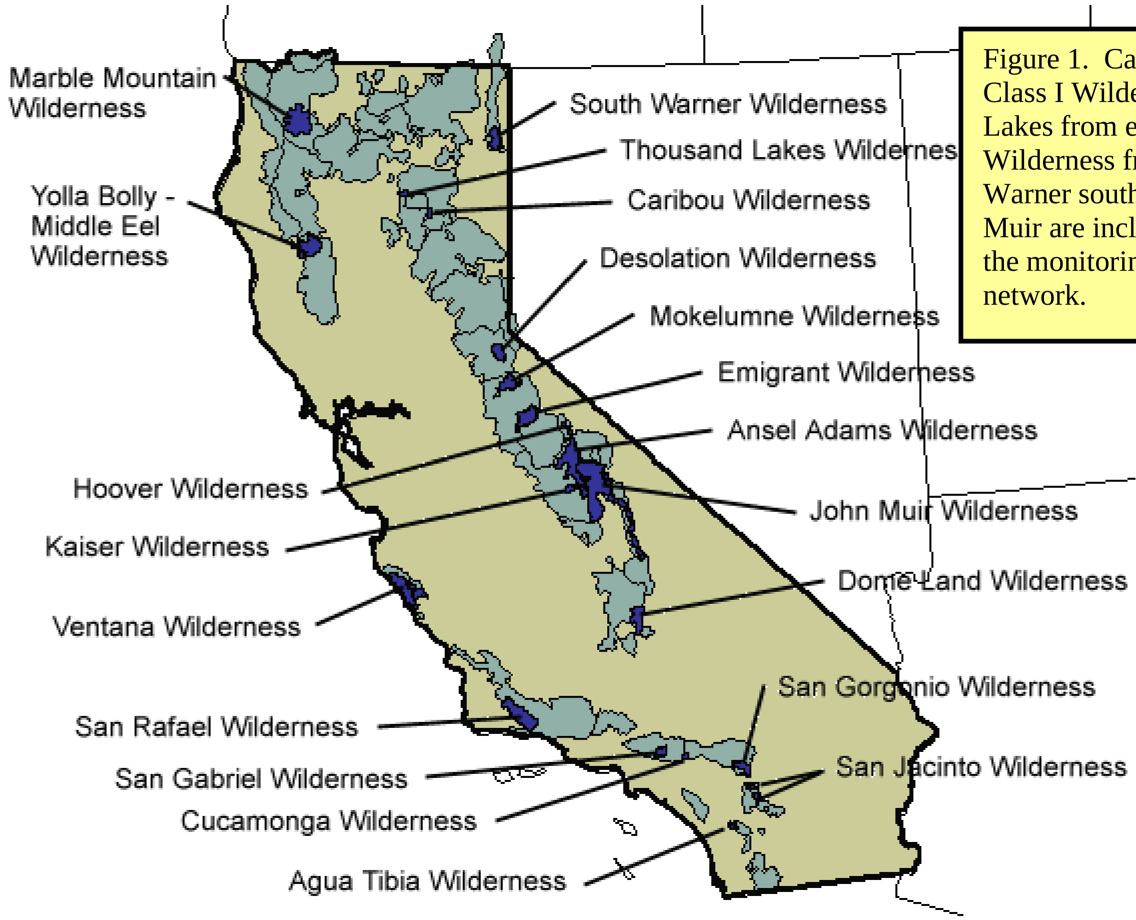



Figure 1. California Class I Wildernesses. Lakes from each Wilderness from S. Warner south to John Muir are included in the monitoring network.

One long-term monitoring lake, Waca in Desolation Wilderness, has been monitored thirteen times since 1985; monitoring of the most of the other lakes began more recently:

| Lake | Wilderness | Years of Data | Years Sampled |
|---|---|---|---|
| Powell | Emigrant | 8 | 2000, 2002-08 |
| Key | Emigrant | 9 | 2000-08 |
| Karls | Emigrant | 6 | 2000, 2003-04, 2006-08 |
| Long | Kaiser | 8 | 2000, 2002-08 |
| Patterson | S. Warner | 7 | 2002-08 |
| Mokelumne 14 | Mokelumne | 7 | 2002-08 |
| Lower Cole Creek | Mokelumne | 7 | 2002-08 |
| Hufford | 1000 Lakes | 7 | 2002-08 |
| Caribou 8 | Caribou | 7 | 2002-08 |
| Waca | Desolation | 13 | 1985, 1991-93, 2000-08 |
| Smith | Desolation | 9 | 1985-86, 1991-92, 2000, 2005-08 |
| Walton | Ansel Adams | 5 | 2004-08 |
| Dana | Ansel Adams | 5 | 2004-08 |
| Little East Marie | Ansel Adams | 4 | 2004, 2006-08 |
| Bullfrog | Dinkey Lakes | 5 | 2004-08 |
| East Chain | John Muir | 3 | 2005, 2007-08 |
| Treasure SE | John Muir | 3 | 2005, 2007-08 |
| Vermillion | John Muir | 3 | 2005, 2007-08 |
| Bench | John Muir | 3 | 2005, 2007-08 |
| East Wahoo | John Muir | 3 | 2005, 2007-08 |
| Cascade | Hoover | 3 | 2006-08 |
| Moat | Hoover | 3 | 2006-08 |

This report addresses lake chemistry and transparency in the context of an early-warning monitoring program for acidification of Wilderness lakes. The monitoring program is not a research study, and relatively minor irregularities in the quality assurance results are not presumed to be causes for major concern.

## 3.0 Objectives

This report has two primary objectives:

1) Assess the quality of selected field procedures and laboratory analyses of lake water samples collected in 2008, specifically to identify any samples that may need re-analysis or that otherwise may require additional action (e.g., revision of sample type/label or deletion of the data).
2) Summarize the relationships between the 2008 lake chemistry and transparency data and information collected in prior monitoring (e.g., trends through time).

This report is not comprehensive in that some components of the 2008 (and earlier) data collection are not evaluated (e.g., data from field data sheets, including water temperature information, and zooplankton data). Nor are other potentially relevant components of the monitoring program comprehensively addressed (e.g., adequacy of training, dataset formalization).

## 4.0 Methods

To address the quality assurance objective, a variety of standardized techniques are available. This assessment focuses on commonly-used techniques described and exemplified in prior assessments for Forest Service lakes (e.g., Turk 2001, Eilers 2003, Eilers et al. 1998) and does not include all possible assessment procedures. The procedures evaluate (1) internal consistency of samples (e.g., transit time, ion balances, calculated versus measured ANC, calculated versus measured conductivity, and outlier assessment), (2) precision through analysis of duplicate samples, and (3) bias or contamination through assessment of field blanks. Lakes with unexpected chemical concentrations are identified in the outlier assessment. Each technique is described briefly below. The data were analyzed with either the Excel® or WQSTAT Plus® software packages.

All samples were analyzed at the USDA Forest Service Rocky Mountain Station analytical laboratory in Ft. Collins, Colorado (hereafter referred to as RM). Concentrations for the following constituents were assessed: conductivity, calcium, magnesium, sodium, potassium, ammonia, fluoride, chloride, nitrate, sulfate, phosphate and ANC. Acidity, as pH, was also evaluated. Detection limits (mg/L and $\mu$Eq $L^{-1}$) are listed below for the major anions and cations:

| Sulfate | Sodium | Ammonia | Chloride | Potassium | Magnesium | Calcium | Nitrate |
|---|---|---|---|---|---|---|---|
| 0.05/1.04 | 0.01/0.44 | 0.01/0.55 | 0.01/0.28 | 0.02/0.51 | 0.02/1.65 | 0.02/1.00 | 0.007/0.113 |

Several of the monitoring lakes were sampled both near the surface (epilimnion) and at depth (hypolimnion) if they were thermally stratified; otherwise the thermally un-stratified long-term lakes were sampled approximately 1 m below the lake surface at a deep-water location. To continue to assess potential differences between mid-lake and lake outlet chemistries, several monitoring lakes were sampled at all three locations contemporaneously (outlet/shoreline, epilimnion and hypolimnion) or both outlet and epilimnion concurrently. Specific sampling and monitoring protocols are detailed in Berg and Grant (2004) for the long-term lakes and in Berg and Grant (2002) for the lakes sampled at the outlet or along the shoreline.

Data analysis follows the draft protocol for long-term lake monitoring being adopted by the national Air Resources Program of the USDA Forest Service (Gurrieri 2006). The summarization objective addresses temporal change with time series plots and tests for statistical trends in chemistry for lakes with at least 6 years of data. The data are first checked for normality (Shapiro-Wilk procedure, Gilbert 1987), then trends are assessed by the nonparametric Mann-Kendall test, with statistically significant trends quantified by Sen's slope estimate (Sen 1968). Caution is needed in interpreting temporal trends for Waca and Smith Lakes because sampling over the years has been undertaken by different agencies and chemical analyses conducted at different laboratories. Differences in procedures could confound statistically significant

temporal trends. Also the samples for trend analysis are from either mid-lake epilimnion or lake outflow locations. Although differences between these locations are typically understood to be minimal (Clow et al. 2002, Musselman 2004), they could also confound identification of temporal trends.

Recommendations are listed at the beginning of this report and documentation of the 2008 chemistry data is given in Appendix I.

# 5.0 Results

## 5.1 Quality Assurance

### 5.1.1 Internal Consistency

#### 5.1.1.1 Transit Time

After collection, samples need to be kept cool to preserve their chemical integrity. Sample warming elevates the risk of biological activity in the sample that could alter the concentration of some chemical constituents. Although refrigerant is included in sample mailing packages the refrigerant has an unknown, but probably relatively short, effective lifespan. All effort should be made to assure sample arrival at the analytical laboratory as soon as possible after collection. To this end a courier system is sometimes used to expedite shipping of samples from lake to trailhead. If needed, samples are stored in a refrigerator rather than mailed over a weekend.

The critical time period is not the total transit time, but the duration that a sample is kept cool by a short-lived refrigerant (e.g., “blue ice”) versus a dedicated coolant (e.g., a refrigerator). Information is not readily available on the time duration samples were cooled by a short-lived refrigerant so the potential for sample degradation due to inadequate cooling can’t be completely assessed. Nevertheless, in general the longer the time between sample collection and receipt at the lab, the greater the chance for sample degradation.

Sixty-nine sample collections (including duplicates) were made from the 22 lakes sampled in 2008 (one lake was sampled twice). Fifty-eight percent of the collections arrived at the laboratory within 3 days of sample collection (compared to 64% in 2003, 62% in 2004, 26% in 2005, 38% in 2006, and 38% in 2007). Over 27% the collections in 2008 had transit times of 5 days or longer, compared to 54% in 2007. The mean transit time was 3.5 days, down from over 5 days in 2007, and down from 4 days in 2006. Compared to earlier years, transit times in 2008 were relatively short—a good sign--particularly compared to 2005-2007.

For the second consecutive year samples from the same lakes (collected on the same dates) had differing transit times. In the extreme, some samples from Hufford and Walton Lakes took 5 days longer in transit time than the other samples from these lakes collected on the same dates. “Duplicate” and “original” samples from some lakes were purposefully sent on different dates, to help assure one or the other was received in a timely fashion. Some of these samples were in transit over a weekend, and therefore had extended transit times. Lakes with relatively long transit times in 2008 were not the same lakes that had long transit times in 2007—also a good sign.

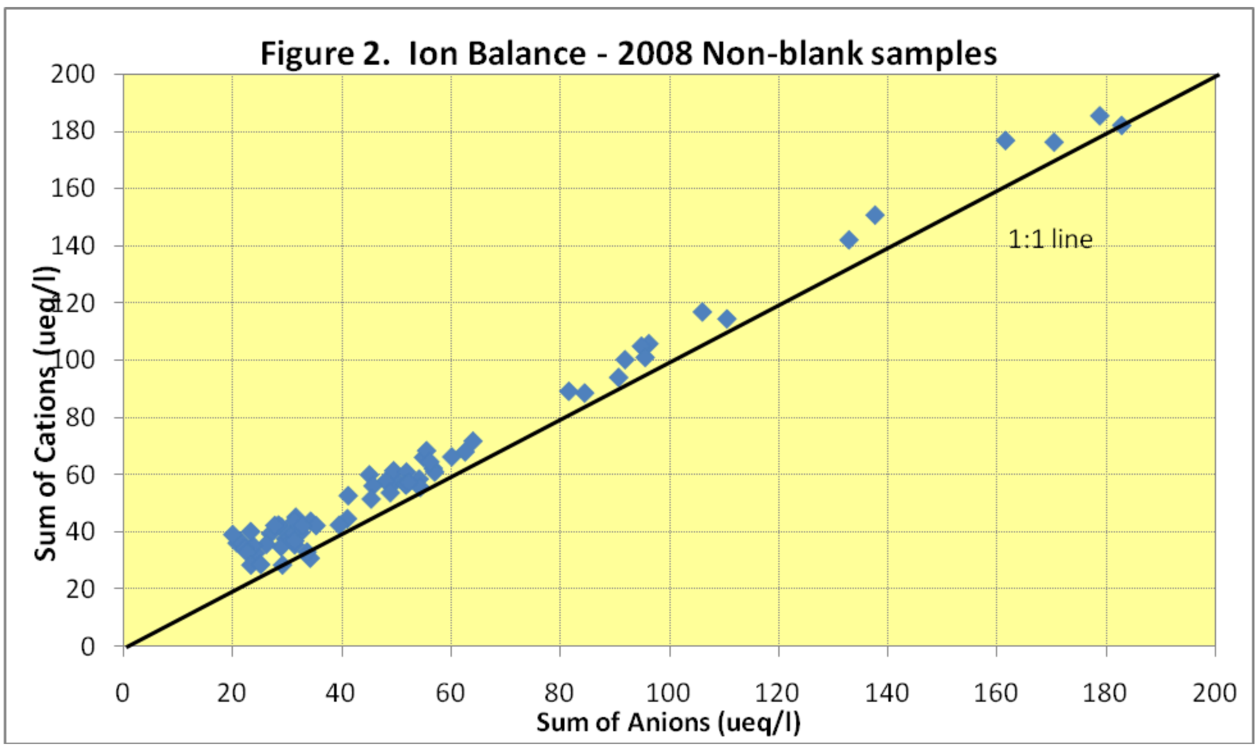
| Transit time (days) | | Number of Lakes | | | | | |
|---|---|---|---|---|---|---|---|
| | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 | 2002 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 2 | 28 | 7 | 6 | 8 | 14 | 3 | 6 |
| 3 | 12 | 9 | 6 | 2 | 4 | 4 | 3 |
| 4 | 10 | 4 | 3 | 7 | 0 | 2 | 25 |
| 5 | 9 | 6 | 6 | 4 | 4 | 1 | 5 |
| 6 | 7 | 4 | 2 | 15 | 5 | 0 | 1 |
| 7 | 3 | 8 | 6 | 4 | 1 | 1 | 1 |
| 8 | 0 | 4 | 0 | 1 | 1 | 0 | 0 |
| >8 | 0 | 5 | 4 | 0 | 0 | 0 | 0 |

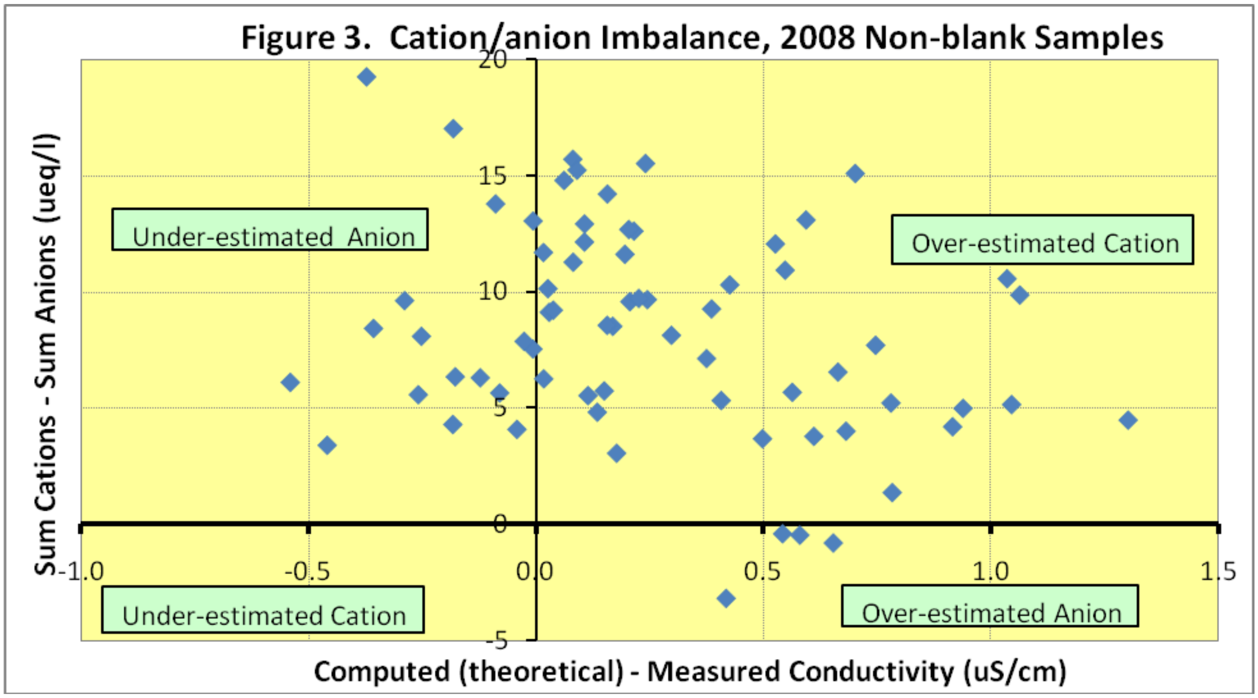
5.1.1.2 Ion Balance

**A** basic premise in ion balance determinations is that the sum of the negatively charged constituents (anions) should balance the sum of the positively charged constituents (cations) in each sample. Analytical procedures are not perfect so typically the ion balance is not exact for a set of samples. Ideally, however, there should be no bias; the sum of the cation minus anion concentrations for a set of samples should approximate zero. Bias is often attributed either to laboratory error or lack of testing for one or more cations or anions. Several related techniques address ion balance, either for potential problems with specific samples or as indicators of overall trends among samples.

Considered as a whole, the chemistry of the 2008 lake samples is slightly biased (Figure 2), and has a consistent under-estimation of the anions or over-estimation of the cations. Over 94% of the 2008 non-blank samples have a greater cation sum than anion sum, and there is an overall average of 8.2 $\mu$Eq $L^{-1}$ cation excess/anion deficiency per sample. This bias compares with averages in 2007, 2006, 2005, 2004, 2003, 2001 and 2000 of 7.5, 13.3, 16.4, 15.9, 9.1, 10.7 and 8.75 $\mu$Eq $L^{-1}$ respectively. Although continuing cation excess/anion deficiency bias has been evident during every year of sample analysis, by the average deficiency metric the 2008 bias is less than in many prior years.

A four-quadrant plot (Figure 3) provides additional information on the cation excess-anion deficiency issue. This plot shows that the bias is best characterized as a slight over-estimation of cations. The cation over-estimation is a departure from all prior years. Through 2007 there was a consistent anion under-estimation. In 2007 the anion under-estimation approximated the cation over-estimation. The approximate equivalency of anion under-estimation to cation over-estimation is a good sign, and although the reasons for the shift from prior years aren't completely known a laboratory instrumentation change occurred before the 2007 analyses were made. Extensive comparisons between results from the old and new instrumentation showed very similar cation concentrations (L. O'Deen personal communication 3/30/09).






The ion imbalance has been evident during all years of sample collection. Samples from dilute waters in other areas can have a similar imbalance, and the relatively improved bias in 2007 and 2008 (versus earlier years) suggests that the ion balance in 2008 is not a major problem.

5.1.1.3. Cation and Anion Sums

The ion balance calculations in section 5.1.1.2 address the chemistry dataset as a whole. For individual samples Turk (2001) identified two triggering values for cation/anion sum problems—to meet "mandatory" and "higher-quality" levels of data quality:

| **Total Ion Strength (cations + anions)** ($\mu$Eq $L^{-1}$) | **% Ion Difference—Mandatory** | **% Ion Difference—Higher Quality** |
|---|---|---|
| <50 | >60 | >25 |
| 50-100 | >30 | >15 |
| ≥100 | >15 | >10 |

Both sets of criteria are percent-based and take into account the fact that percentage values increase for the same absolute differences in concentrations as concentration levels decrease. The percent of samples meeting the two criteria are listed below for monitoring years 2002-2008:

| **Year** | **% Meeting Mandatory Criterion** | **% Meeting Higher Quality Criterion** |
|---|---|---|
| 2008 | 99 | 74 |
| 2007 | 99 | 85 |
| 2006 | 99 | 74 |
| 2005 | 91 | 73 |
| 2004 | 90 | 20 |
| 2003 | 100 | 83 |
| 2002 | 100 | 87 |

In comparison to earlier years, the 2008 data are comparable in terms of meeting the mandatory standard although several earlier years had a higher percentage of samples that met the higher quality criterion.

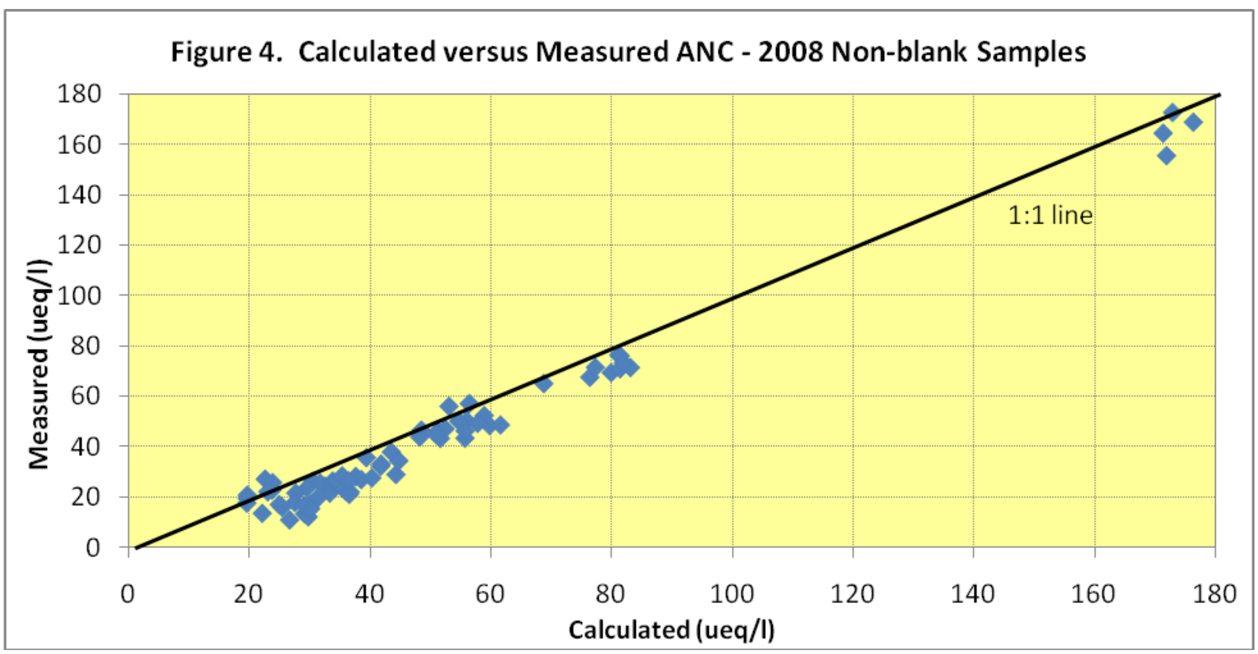
The one 2008 sample not meeting the mandatory criteria is from the shoreline of Mokelumne 14 Lk (Mokelumne Wilderness), and many of the samples not meeting the higher quality standard are from low-ANC lakes (e.g., Cascade, Smith, Karls). 2007 lakes not meeting the high quality criteria generally met the high quality criteria in 2008 (e.g., Long and Powell Lakes), implying there is no obvious issue with specific lakes over time.

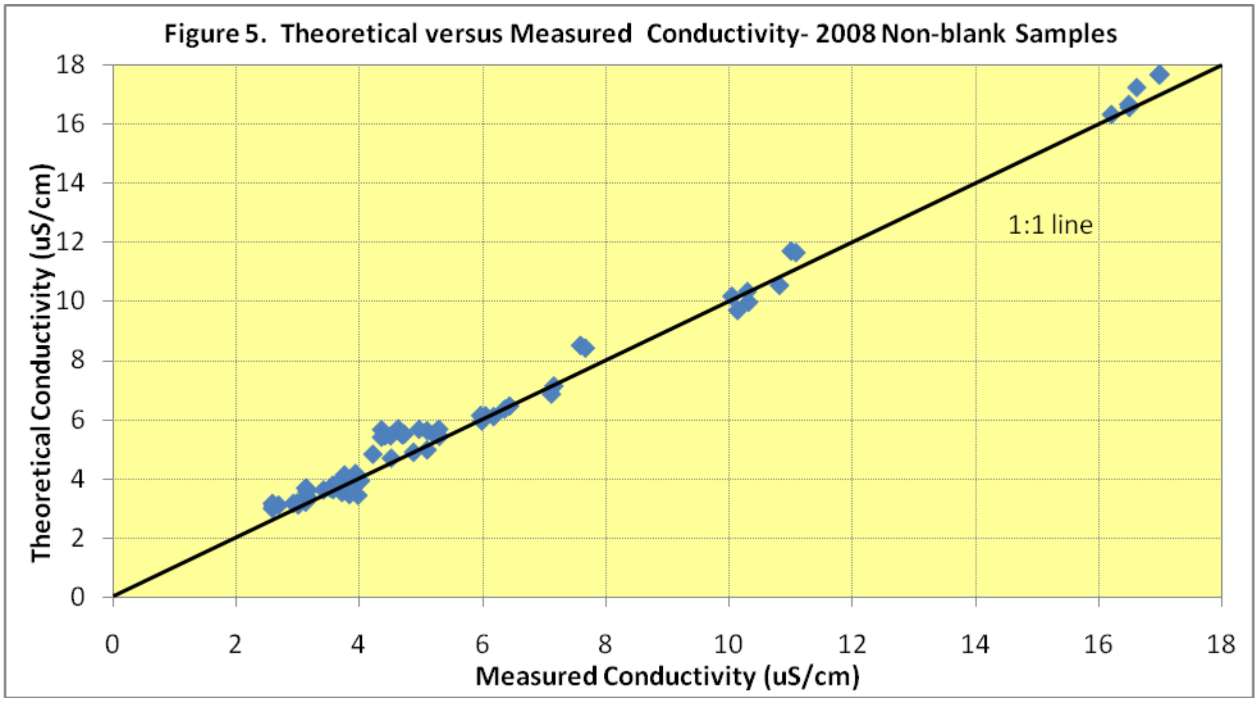
#### 5.1.1.4 Calculated versus Measured ANC

**A**nother index of potential ion imbalance is the comparison of measured ANC against ANC calculated as the difference in the sum of base cations (calcium + magnesium + sodium + potassium) and acid anions (sulfate + chloride + nitrate). A bias similar to the historical/pre-2008 ion imbalance also exists for the 2008 ANC comparison (Figure 4). The calculated value on average is 7.8 $\mu$Eq $L^{-1}$ greater than the measured value (compared to 7.5 $\mu$Eq $L^{-1}$ greater in 2007, 11.6 $\mu$Eq $L^{-1}$ greater in 2006, 15.8 $\mu$Eq $L^{-1}$ greater in 2005, 15.65 $\mu$Eq $L^{-1}$ greater in 2004 and 7.55 $\mu$Eq $L^{-1}$ greater in 2003), with 93% of the individual samples having greater calculated than measured ANC. No single sample, or a small number of samples, appears to dominate the bias; a shift from the 1:1 line in Figure 4 is evident for most samples. One-third of the non-blank 2008 samples had calculated minus measured ANCs > 10 $\mu$Eq $L^{-1}$ (compared to 31% in 2007, 43% in 2006, 54% in 2005, 80% in 2004 and 27% in 2003). Eilers et al. (1998) label samples having calculated minus measured ANCs > 5 $\mu$Eq $L^{-1}$ as “outliers”. By this definition 75% of the 2008 samples would be “outliers” (compared to 59% in 2007, 42% in 2006, 79% in 2005 and over 92% in 2004). Although the imbalance between calculated and measured ANC is further evidence that either one or more constituents aren’t being analyzed--or there are laboratory problems--by this measure the 2008 sample analysis is of approximately equal quality to analyses from most of the prior years.

#### 5.1.1.5 Theoretical versus Measured Conductivity

**T**he measured versus theoretical conductivities from the 2008 lake samples show most samples (93%) to be within the +/-1 $\mu$S $cm^{-1}$ criterion used by Eilers et al. (1998) to identify “outlier” values (Figure 5). The 93% value is better than the average for several prior years (96% in 2007, 86% in 2005 and 2006, and 88% in three other prior years). In a broader comparison, less than 70% of the 1985 Western Lake Survey samples from Sierran lakes were within the +/-1 $\mu$S $cm^{-1}$ criterion.






Four samples collected in 2008—epilimnion duplicates from Vermilion Lk, and epilimnion and shoreline samples from Treasure Lk SE--exceeded Eilers et al.'s +/- 1 µS $cm^{-1}$ criteria. The criterion value for all four samples was close to the threshold, 1.3, 1.05, 1.06 and 1.04 µS $cm^{-1}$, suggesting little cause for concern.

Per this metric there is some bias in the 2008 samples—26% of the non-blank samples have greater measured than calculated conductivity (compared to 50% in 2007, over 70% in 2006, 89% in 2005, 80% in 2004 and 75% in 2003)—although the mean bias is small, 0.13 µS $cm^{-1}$. Eilers (2003) described Gallatin National Forest lake samples with approximately this amount bias as not presenting "… a significant concern with respect to the quality of the data".

### 5.1.1.6 Outliers

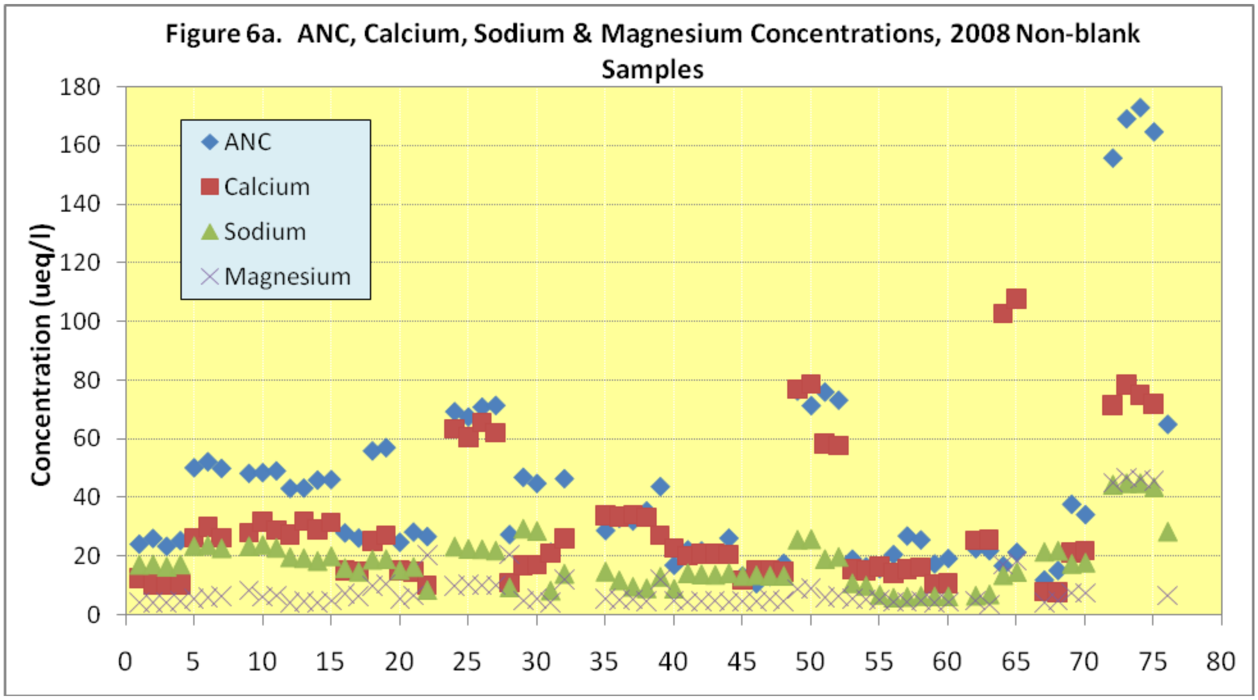
**O**utliers are extreme values that are inexplicable. Contamination by body contact with sample liquid, for instance, is typically identified by outlier values of sodium and chloride. For all 2008 non-blank samples, concentrations of calcium, sodium, magnesium, ANC, chloride, nitrate and sulfate are plotted in Figure 6. Outliers are assessed visually and statistically using Dixon's outlier test.

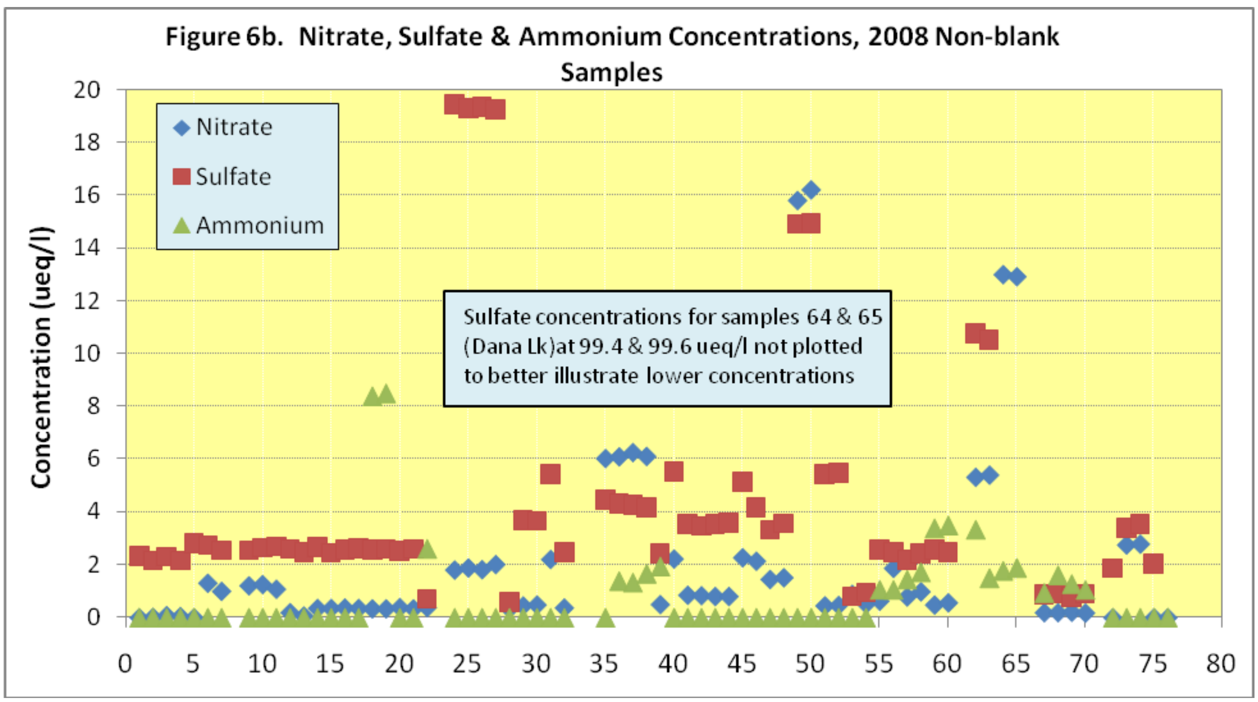
#### 5.1.1.6.1 Visual assessment

**F**ive pairs of duplicate samples--from the epilimnion and hypolimnion at Patterson Lk, the epilimnion at Bench and Dana Lakes, and the hypolimnion at Powell Lk--had particularly high concentrations of ammonium, nitrate, sulfate, or ANC (Figures 6a and b—samples 72-75, 49-50, 64-65, 18-19 respectively for Patterson, Bench, Dana and Powell Lakes). In addition, the duplicated epilimnion samples from Dana Lk exhibited moderately high calcium concentrations. Even though these concentrations were as much as five fold larger than the next highest concentration (e.g., sulfate at Dana Lk), in all cases there is historical precedent for these high concentrations at these lakes, and the high concentrations are not considered to be a problem. For instance, the chemistry at Patterson Lk has always differed appreciably from the other lakes in the monitoring network in having much higher concentrations of ANC, potassium, sodium and magnesium. Similarly, Dana Lk has always had high sulfate and nitrate. Both Patterson and Dana have always had the highest concentrations of the constituents in question of any lake in the monitoring network. Reasons for these high concentrations have been addressed in earlier annual reports, and have been speculatively attributed to geological influences and atmospheric transport from east of the Sierra Nevada. High ammonium concentrations in the hypolimnion samples from Powell Lk are less explicable. In 2004 and 2007 the single hypolimnion sample from each of these years had 0 ammonium. In 2005 and 2006, however, the ammonium concentrations from the Powell hypolimnion were the

highest in each year (4.4 and 10.6 μEq $L^{-1}$ respectively) of any lake sampled. Reasons for these high hypolimnion concentrations are not addressed here, but the historical precedent suggests that the high ammonium at Powell Lk in 2008 is not a quality control problem.

To put the "high" concentrations into further perspective, some lakes sampled in the 1985 Western Lake Survey (Landers et al. 1987) had high calcium and sulfate concentrations (e.g., Hoover Lake in Hoover Wilderness, with sulfate = 386 μEq $L^{-1}$ and calcium = 493 μEq $L^{-1}$). And lakes outside of the Sierra commonly have higher concentrations. For instance, the mean calcium and ANC concentrations of 1,798 lakes surveyed in the Eastern Lake Survey were 245 and 264 μEq $L^{-1}$ respectively (Kanciruk et al. 1986).




5.1.1.6.2 Statistical assessment

**D**ixon's outlier test (Dixon 1953, NIC 2005) assumes data are distributed normally or log normally and tests whether a suspect value fits the distribution of the rest of the data set. At the 0.05 level of statistical significance, Dixon's test identified no outliers for ANC, conductivity, calcium, chloride, potassium, magnesium, sodium, or nitrate at any lake. However, both duplicate shoreline samples at Dana Lake in Ansel Adams Wilderness were identified as statistical outliers for sulfate, as were both Patterson Lake epilimnion samples for pH. Sulfate concentrations at Dana have ranged from nearly 60 to over 120 μEq $L^{-1}$ during each monitoring year from 2004 to 2008 period, implying that the 2008 high sulfate concentrations are not atypical. These values are much higher than the median sulfate concentration in 2008 (for all samples) of 2.7 μEq $L^{-1}$, implying that significantly high sulfate at Dana Lake is to be expected in the Dixon outlier test. Similarly, pH at Patterson Lake has always been relatively high, and often a full pH unit above those at other lakes in the monitoring network. The 2008 Patterson pHs, at 8.0 and 7.9, are greater than in any prior year, but on balance are not believed to be erroneous.

For these reasons it does not appear that either the pH values nor the sulfate concentrations from Patterson and Dana Lakes in 2008 are problematic, and these values are retained in the dataset.

<u>5.1.2 Precision -- Duplicate Samples</u>

**T**hirty-four "duplicate" pairs of samples were collected in 2008 from shallow mid-lake locations (16 lakes), at lake outlets or along the shoreline (11 lakes), and seven samples from the hypolimnion. Most of the duplicates were collected about 5 minutes apart. These duplicates should be nearly identical in their constituent concentrations. A measure of chemical variation, the percent relative standard deviation (%RSD), was calculated for all duplicates for ANC, calcium, nitrate, conductivity, magnesium, sodium, chloride, potassium and sulfate concentrations. Per B. Gauthier (5/30/02 email to J. Peterson) the %RSD for duplicate samples should be less than or equal to 10%. For each constituent the following table lists the percentage of the pairs of duplicate samples with %RSD greater than 10% for samples collected between 2001 and 2008:

| | **2008** | **2007** | **2006** | **2005** | **2004** | **2003** | **2002** | **2001** |
|---|---|---|---|---|---|---|---|---|
| <u>Number of Duplicate Pairs</u> | 34 | 45 | 18 | 9 | 8 | 14 | 11 | 12 |
| <u>Chemical Constituent</u> | | | | | | | | |
| ANC | 24 | 33 | 33 | 44 | 43 | 23 | 55 | 8 |
| Calcium | 6 | 22 | 0 | 11 | 14 | 38 | 36 | 25 |
| Nitrate | 33 | 79 | 61 | 0 | 29 | 8 | 0 | 9 |
| Conductivity | 0 | 0 | 0 | 22 | 0 | 46 | 18 | 17 |
| Magnesium | 12 | 44 | 0 | 11 | 29 | 8 | 36 | 8 |
| Sodium | 6 | 7 | 0 | 22 | 14 | 8 | 9 | 8 |
| Potassium | 29 | 38 | 22 | 22 | 57 | 8 | 18 | 8 |
| Chloride | 32 | 47 | 28 | 56 | 29 | 23 | 27 | 17 |
| Sulfate | 9 | 18 | 17 | 22 | 0 | 23 | 9 | 25 |

For the %RSD metric—
- Compared to earlier years the 2008 duplicate samples were more precise than 2007 and ranked about "average" compared to the %RSDs for the group of prior years.
- Many constituents have %RSD values above the 10% criteria for some years, implying a fair amount of "noise" in the laboratory analyses, the sample collection, handling and transport procedures, or some combination of all three activities.

The %RSD calculation procedure is sensitive to "sample size". Calculation of standard deviations on the basis of two values is marginal; typically at least three values are used, and ideally a much larger sample size should be the basis for the %RSD calculation. The relatively high values listed in the table above for some years may be partially due to this sample size effect.

Another reason for some relatively high %RSD values, particularly for nitrate, may be low concentrations, near or below the detection limit. For instance, the concentrations of the two nitrate duplicates from hypolimnion samples taken from East Chain Lk in 2008 were low, 0.06 and 0.35 μEq $L^{-1}$. Nevertheless the %RSD for these duplicates is 98%, much

greater than the 10% threshold value. Also the 2008 median difference in nitrate, sulfate, ammonium, sodium and chloride is below 0.05 μEq $L^{-1}$, a very low magnitude. This low median difference suggests that although the 2008 %RSD values for some duplicates are high, the absolute value of the differences is generally small. Last, for nitrate, and ammonium in particular, many samples have had undetectable concentrations during most years, suggesting that these constituents occur in very low concentrations in the lakes sampled.

ANC is the single best constituent for %RSD assessment because it tends to integrate the concentrations of several of the other constituents. ANC is also the single best correlate with potential acidification. The largest ANC %RSD values in 2008 ranged between 15 and 21. In contrast in 2007 Bullfrog Lake's epilimnion %RSD was 40, almost twice that of the second greatest ANC %RSD from 2007. The lakes with relatively high (15-21) %RSD in 2008 all had low ANCs and the absolute difference in the ANCs were relatively small (e.g., 16.9 and 21.5 μEq $L^{-1}$from shoreline samples at Dana Lk). The small absolute ANC difference is promising and suggests that the laboratory and field sample collection procedures are of high quality.

Most of the 2008 duplicates had only one or two %RSD values greater than 10. Duplicates from two low-ANC lakes, Karls (Emigrant Wilderness) and Waca (Desolation Wilderness) had %RSD values greater than 10 for four and five constituents respectively. Except for nitrate (%RSD =70) at Waca and nitrate and chloride (%RSD =37 and 40 respectively) at Karls, the %RSD values were relatively low, in the 10-20 range. The high %RSD for nitrate may be explained by the low absolute nitrate values—e.g., 0.5 and 0.9 μEq $L^{-1}$ for the two Karls Lk shoreline samples--where even a small absolute difference between duplicates can produce a relatively large percent difference. In 2007 Little East Marie Lk (Ansel Adams Wilderness) had %RSD values greater than 40 for sulfate, magnesium and hydrogen. These higher %RSD values were not repeated in 2008, suggesting that no systematic problem exists at Little East Marie.

The mean absolute differences between the duplicates (the precision) for major chemical constituents are compared below for years 2003 through 2008.

| Constituent | Unit | Mean Absolute Difference | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 |
| ANC | μEq $L^{-1}$ | 2.83 | 3.36 | 4.33 | 3.62 | 2.35 | 3.18 |
| Conductivity | μS $cm^{-1}$ | 0.13 | 0.34 | 0.30 | 1.36 | 0.49 | 0.22 |
| Calcium | μEq $L^{-1}$ | 1.35 | 2.48 | 0.85 | 1.08 | 1.34 | 1.91 |
| Magnesium | μEq $L^{-1}$ | 0.53 | 0.84 | 0.30 | 0.29 | 0.80 | 0.72 |
| Sodium | μEq $L^{-1}$ | 0.61 | 0.65 | 0.29 | 1.12 | 2.70 | 0.72 |
| Potassium | μEq $L^{-1}$ | 0.56 | 0.50 | 0.26 | 8.81 | 1.91 | 0.34 |
| Chloride | μEq $L^{-1}$ | 0.36 | 0.53 | 0.17 | 7.94 | 0.16 | 0.62 |
| Sulfate | μEq $L^{-1}$ | 0.13 | 1.22 | 0.89 | 0.20 | 0.33 | 0.24 |
| Nitrate | μEq $L^{-1}$ | 0.16 | 0.20 | 0.20 | 0.03 | 0.25 | 0.09 |

Compared to the earlier years, the 2008 results are lower than average for several constituents and are the lowest recorded thusfar for sulfate and conductivity.

In a study of lake waters on the Mt. Baker-Snoqualmie National Forest in Washington, Eilers et al. (1998) characterized samples with mean absolute differences $\leq$ 1.0 μEq $L^{-1}$ as dilute waters. Except for ANC and calcium, the 2008 Sierran samples match this criterion for dilute lake water.

On the basis of the 2008 %RSD analysis there is no obvious reason to suggest a problem(s) with either any particular lake samples or the broader sample collection and analysis procedures.

5.1.3 Bias -- Field Blanks

**T**o help assure that water collection bottles are not contaminating samples, "field blanks" have water—typically de-ionized with very low or undetectable constituent concentrations—that is stored in the bottles for time periods comparable to the amount of time sample water remains in a bottle prior to analysis. Field blanks are typically sent out by the laboratory with the other bottles and taken to the field along with the actual sample bottles. Common contaminants in the

field blanks are sodium and chloride, from perspiration, or elevated acidity as a residue from prior cleaning of the bottle. The QA/QC protocol for the chemistry laboratory at the Riverside unit of the Forest Service's Pacific Southwest Research Station states that "[T]he value of a blank reading should be less than $\pm$0.05 mg $L^{-1}$ from zero". Eilers et al. (1998) used 1.0 μEq $L^{-1}$ for individual cations as a trigger value for blank contamination and the FS national air program (USDA Forest Service 2007) states that ideally conductivity in blanks should be less than 2 uS/cm.

Seven field blanks were incorporated into the 2008 sample collection. Fifty-seven percent of 70 constituent analyses (ten constituents for each blank) had detectable results, compared with 50% in 2007, 42% in 2006 and 33% in 2005. This, and other comparisons to prior years, is conditioned by a change in nitrate detection limit in 2008, down to .007 mg/l (0.113 ueq/l) compared to 0.02 mg/l (0.65 ueq/l) in prior years. Over 46% of the blank cation concentrations were greater than Eilers et al's 1.0 μEq $L^{-1}$, with all calcium blank samples ranging from 1.4 to 6.2 μEq $L^{-1}$. The only constituents with concentrations greater than PSW Station's $\pm$0.05 mg $L^{-1}$ criterion were ammonium and calcium, with calcium accounting for two-thirds of the total. Relatively high calcium concentrations in the blanks is common from prior years as well. Conductivity in all seven blanks ranged from 0.8 to 1.0 uS/cm, lower than 2007's 1.23 to 1.85 uS/cm range.

In summary, the field blank assessment does not appear to identify a systematic problem with sample collection although relatively high calcium concentrations continue, as in most prior years. No individual blank samples were identified as problematic.

#### 5.1.4 Summary of Quality Control Findings

**T**he 2008 quality control analyses did not identify any new or unexpected issues, and for all QA/QC metrics the 2008 data are on par or better than in all prior years. The single most notable QA/QC result is the shift in 2008 away from persistent anion under-estimation through most prior years to an approximate equivalency of anion under-estimation to cation over-estimation in 2008

### 5.2 Time Trends for Long-term Monitoring Lakes

**E**leven lakes have been monitored at least six times (see table on page 4), with one of these, Waca in Desolation Wilderness, sampled thirteen times since 1985. A monitoring duration of 5 or 6 years is minimal for preliminary assessment of temporal change, and the literature suggests that typically a much longer time period is needed before temporal trends can be statistically verified. To offer a preliminary assessment of temporal change, plots of the chemistry of the eleven lakes are presented in Figure 7, and the results of a trend analysis are presented.

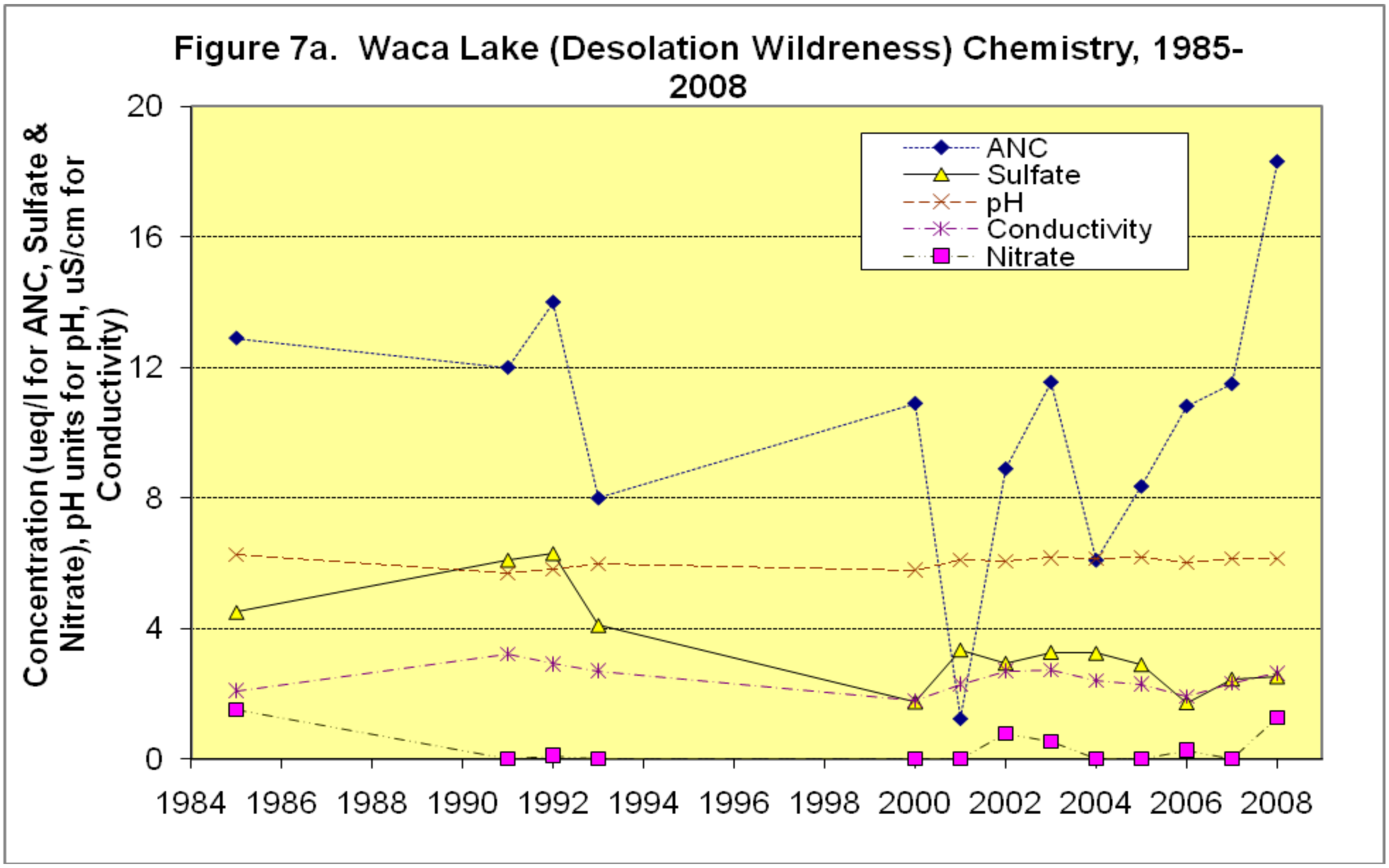


Figure 7a. Waca Lake (Desolation Wilderness) Chemistry, 1985-2008
Concentration (ueq/l for ANC, Sulfate & Nitrate), pH units for pH, uS/cm for Conductivity)
ANC
Sulfate
pH
Conductivity
Nitrate
0
4
8
12
16
20
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008

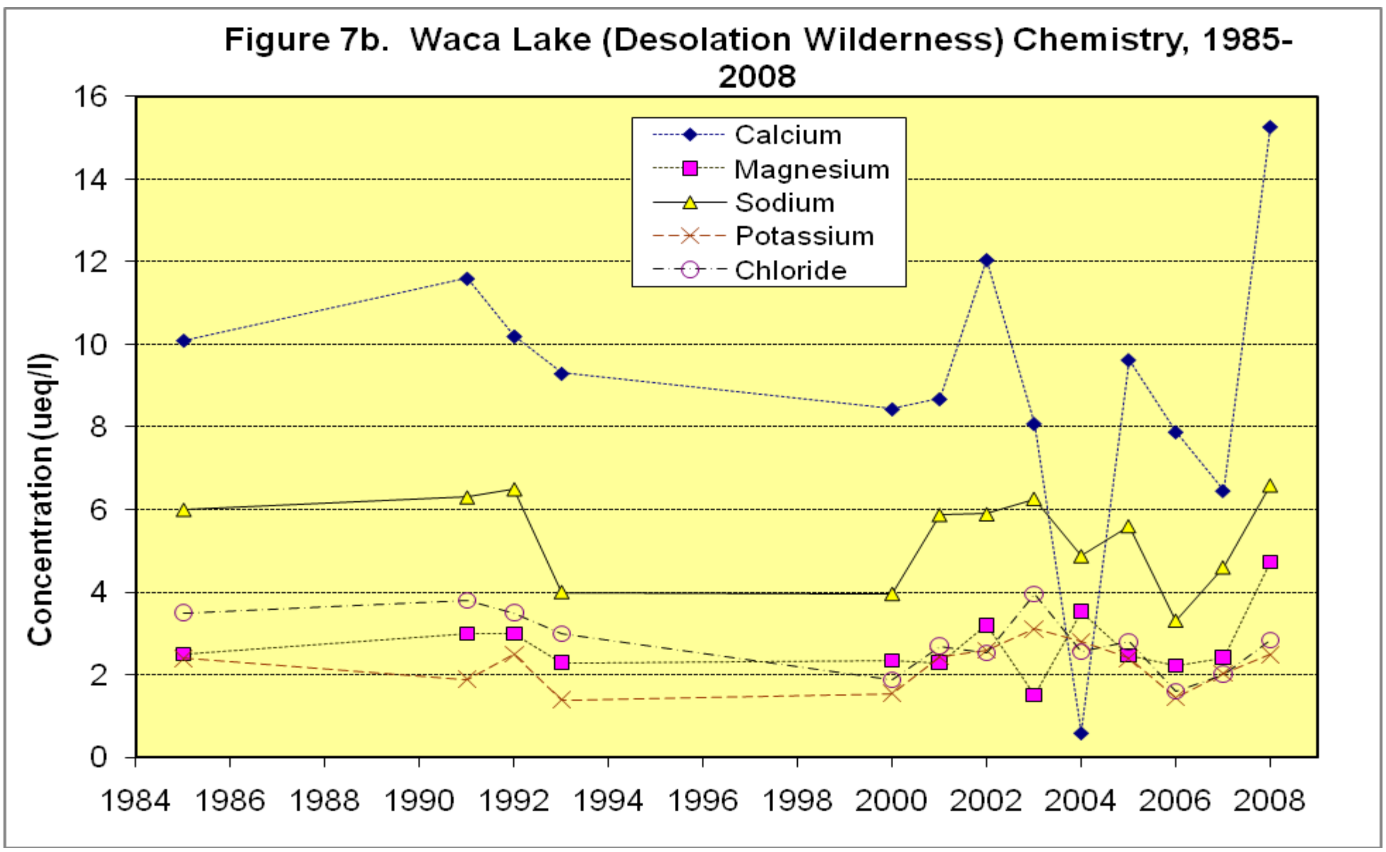


Figure 7b. Waca Lake (Desolation Wilderness) Chemistry, 1985-2008
Concentration (ueq/l)
Calcium
Magnesium
Sodium
Potassium
Chloride
0
2
4
6
8
10
12
14
16
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008

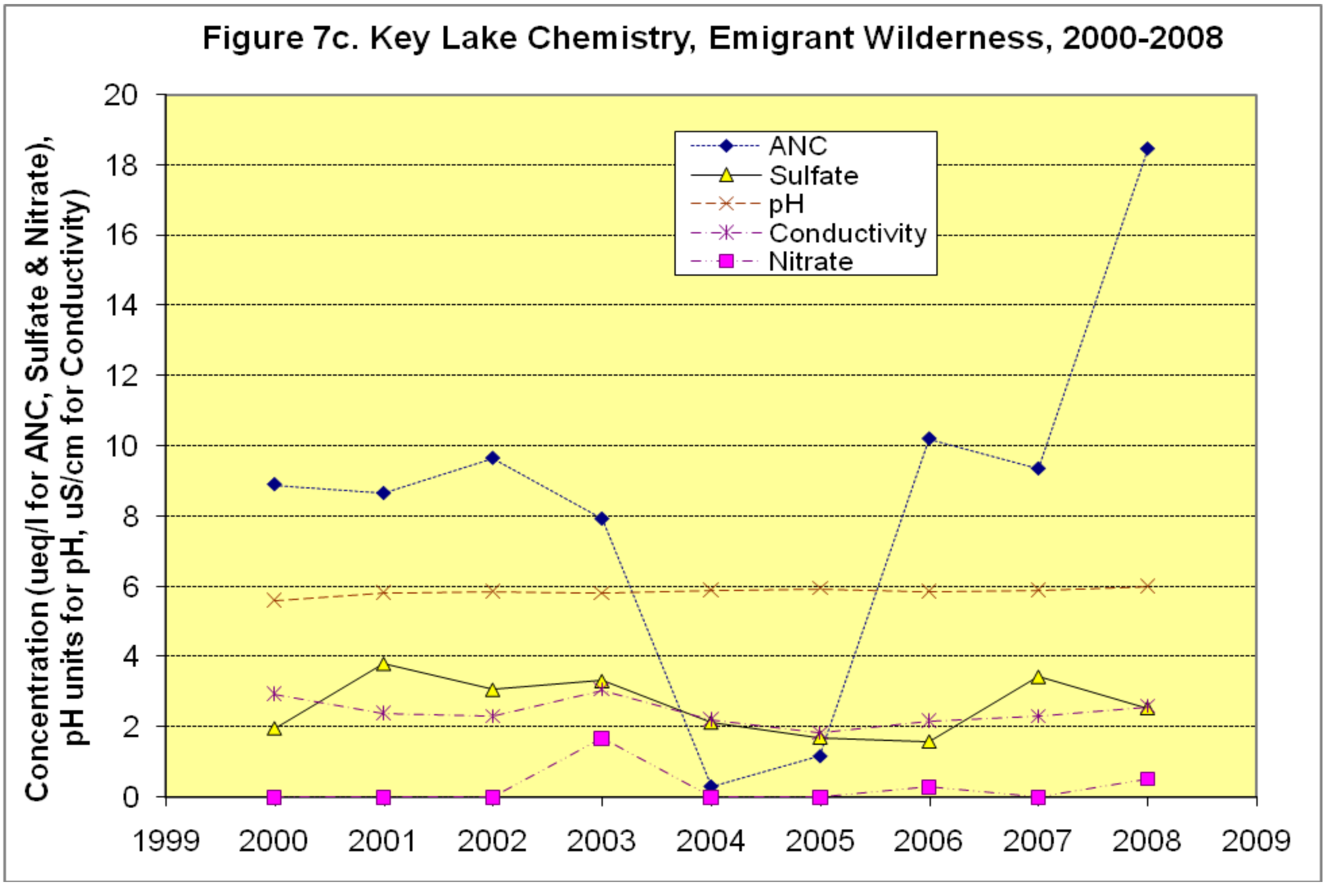


Figure 7c. Key Lake Chemistry, Emigrant Wilderness, 2000-2008
Concentration (ueq/l for ANC, Sulfate & Nitrate), pH units for pH, uS/cm for Conductivity)
ANC
Sulfate
pH
Conductivity
Nitrate
20
18
16
14
12
10
8
6
4
2
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

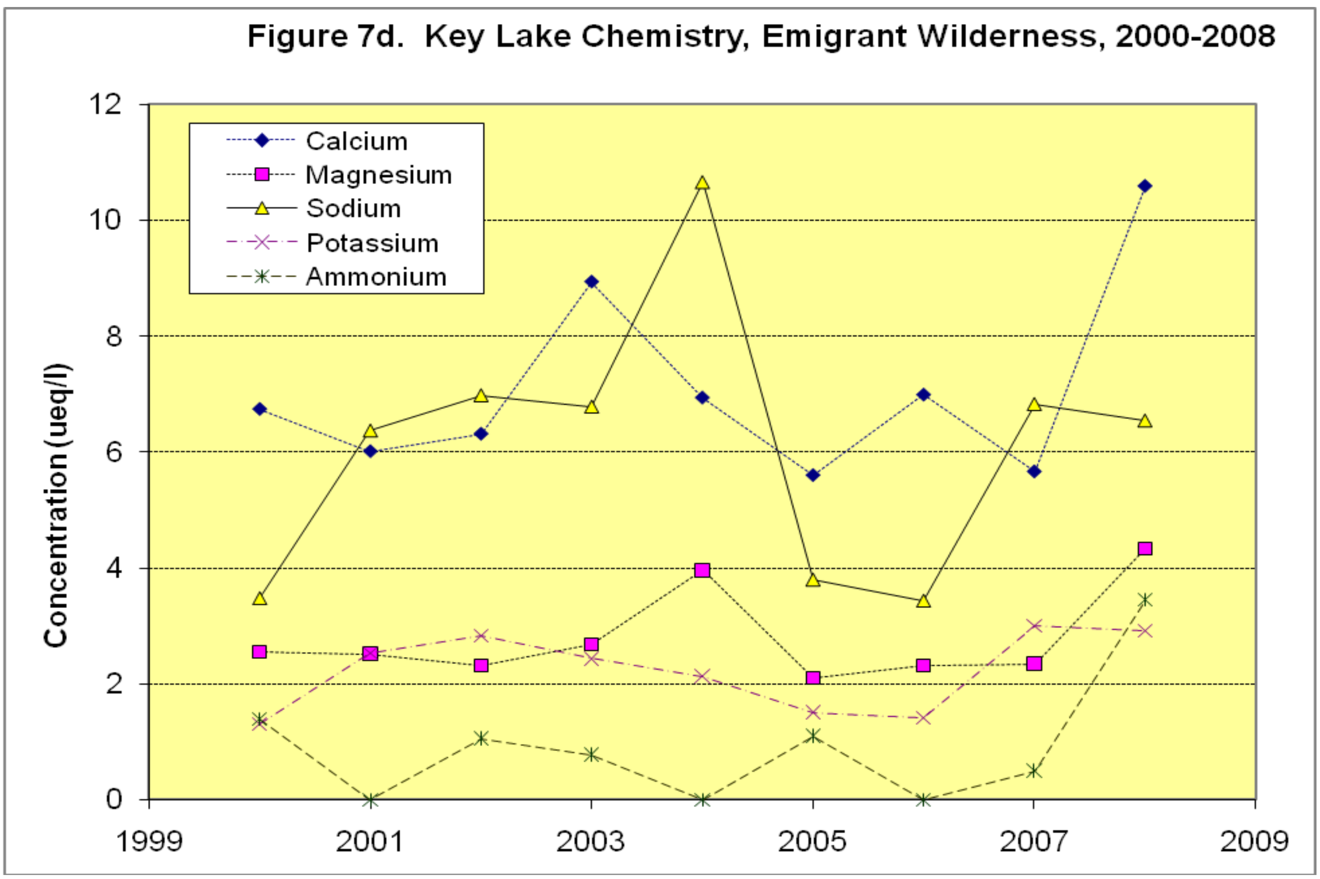


Figure 7d. Key Lake Chemistry, Emigrant Wilderness, 2000-2008
Concentration (ueq/l)
Calcium
Magnesium
Sodium
Potassium
Ammonium
12
10
8
6
4
2
0
1999
2001
2003
2005
2007
2009

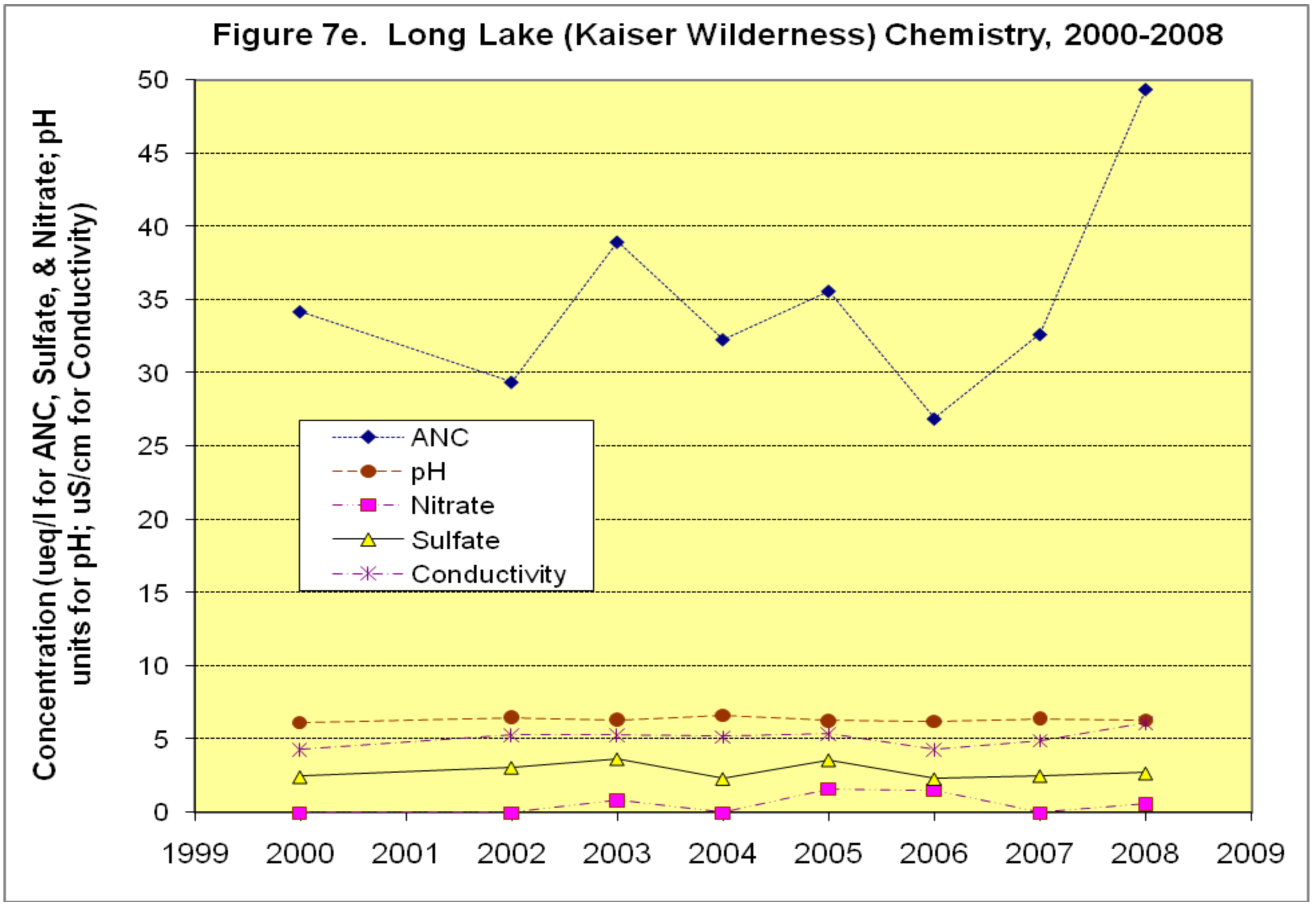


Figure 7e. Long Lake (Kaiser Wilderness) Chemistry, 2000-2008
Concentration (ueq/l for ANC, Sulfate, & Nitrate; pH units for pH; uS/cm for Conductivity)
50
45
40
35
30
25
20
15
10
5
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
ANC
pH
Nitrate
Sulfate
Conductivity

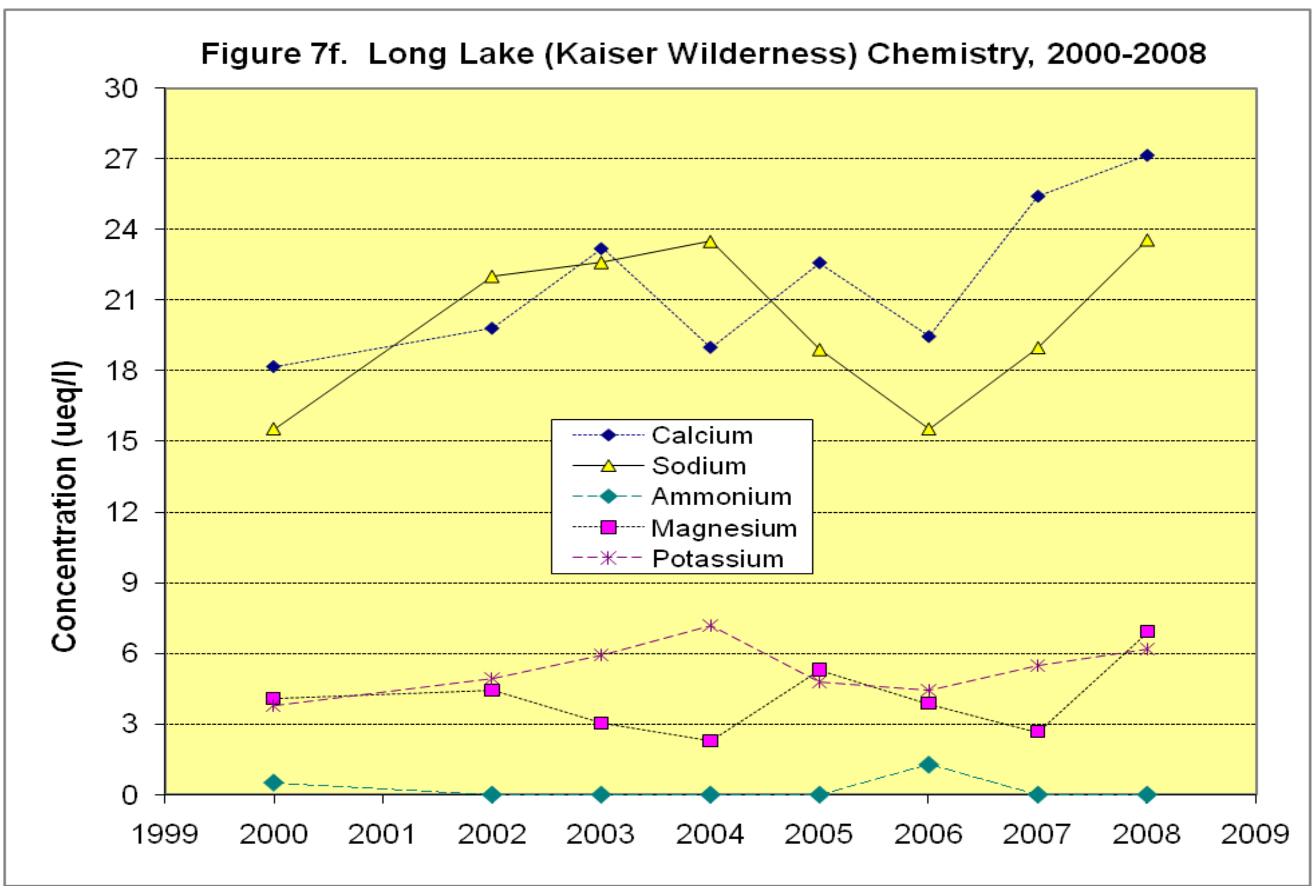



Figure 7f. Long Lake (Kaiser Wilderness) Chemistry, 2000-2008
Concentration (ueq/l)
30
27
24
21
18
15
12
9
6
3
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Calcium
Sodium
Ammonium
Magnesium
Potassium

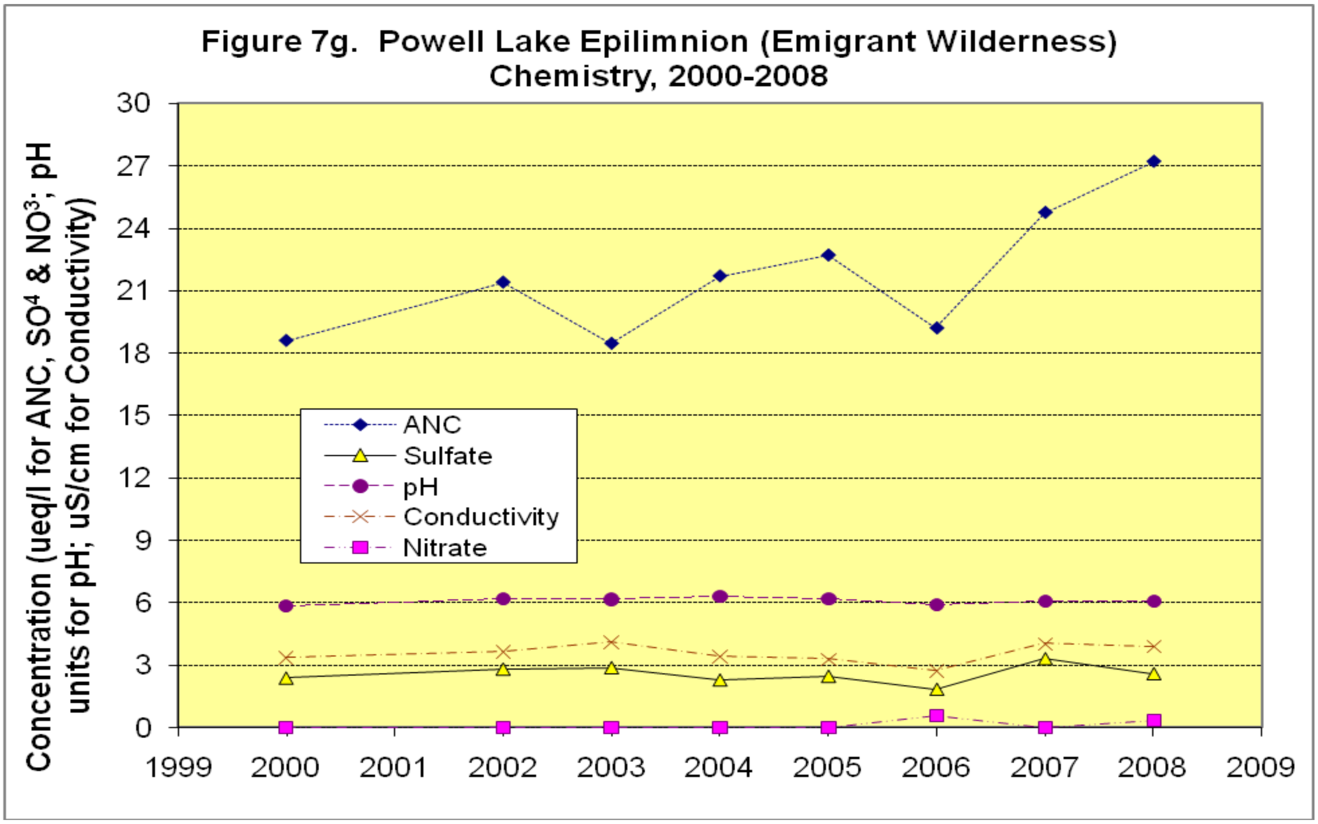


Figure 7g. Powell Lake Epilimnion (Emigrant Wilderness) Chemistry, 2000-2008
Concentration (ueq/l for ANC, SO4 & NO3; pH units for pH; uS/cm for Conductivity)
30
27
24
21
18
15
12
9
6
3
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
ANC
Sulfate
pH
Conductivity
Nitrate

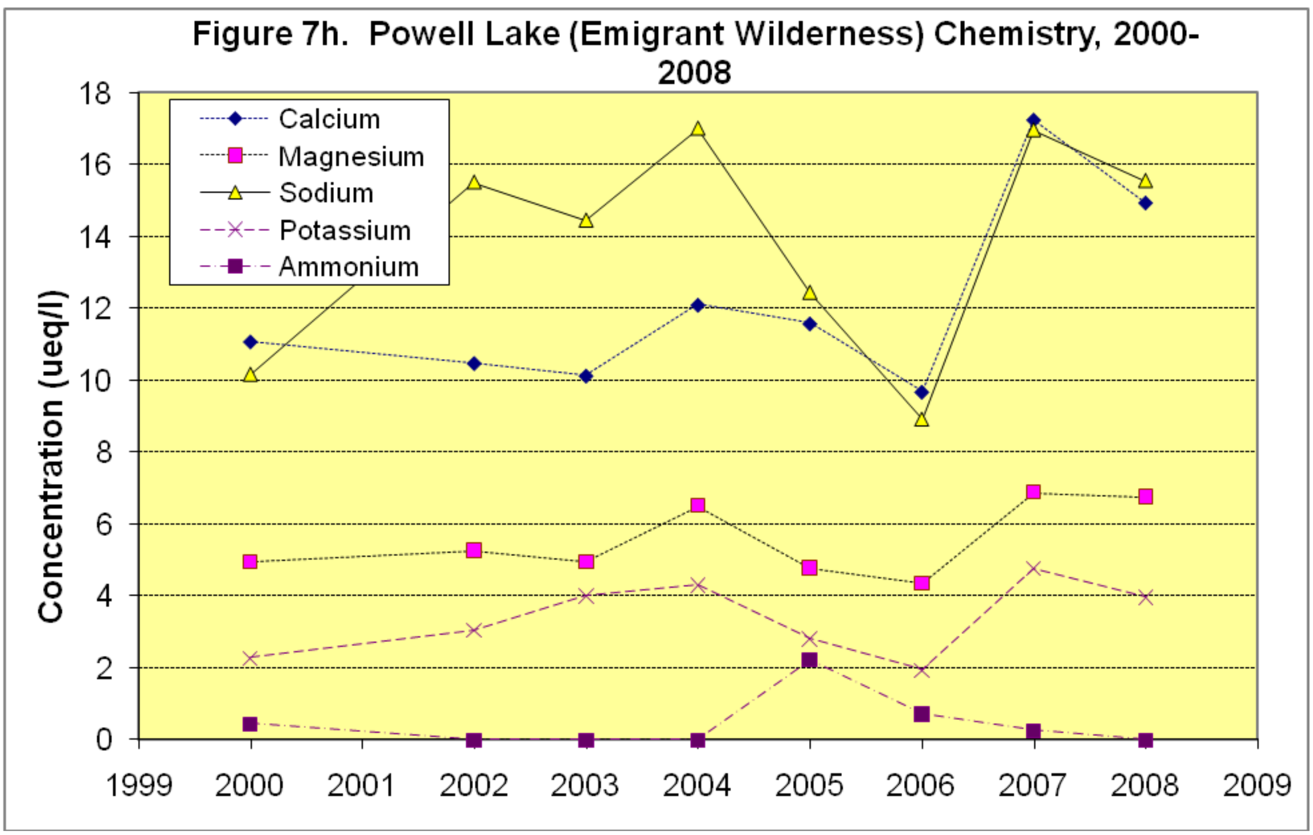


Figure 7h. Powell Lake (Emigrant Wilderness) Chemistry, 2000-2008
Concentration (ueq/l)
18
16
14
12
10
8
6
4
2
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Calcium
Magnesium
Sodium
Potassium
Ammonium

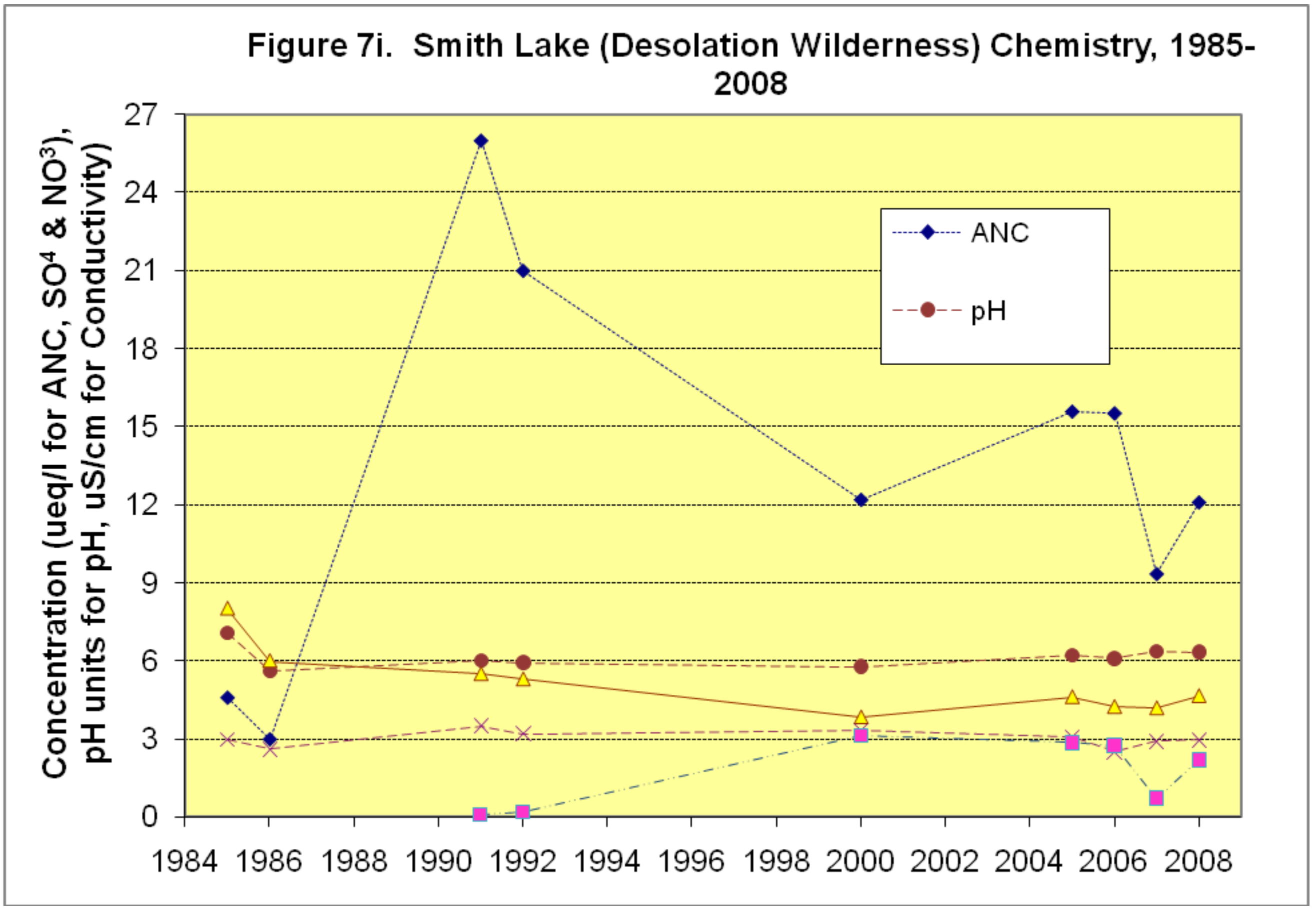


Figure 7i. Smith Lake (Desolation Wilderness) Chemistry, 1985-2008
Concentration (ueq/l for ANC, SO4 & NO3), pH units for pH, uS/cm for Conductivity)
ANC
pH
27
24
21
18
15
12
9
6
3
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008

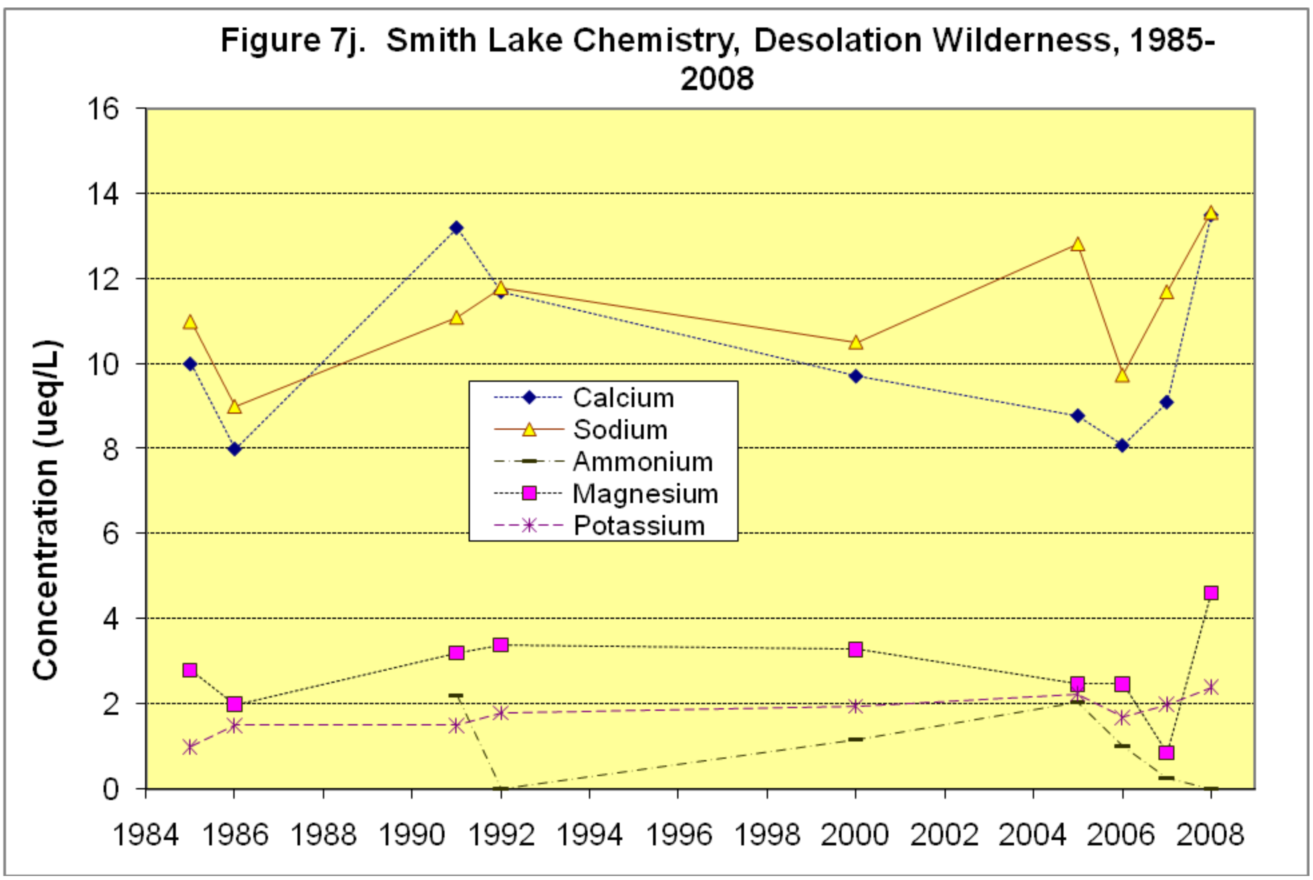


Figure 7j. Smith Lake Chemistry, Desolation Wilderness, 1985-2008
Concentration (ueq/L)
Calcium
Sodium
Ammonium
Magnesium
Potassium
16
14
12
10
8
6
4
2
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008

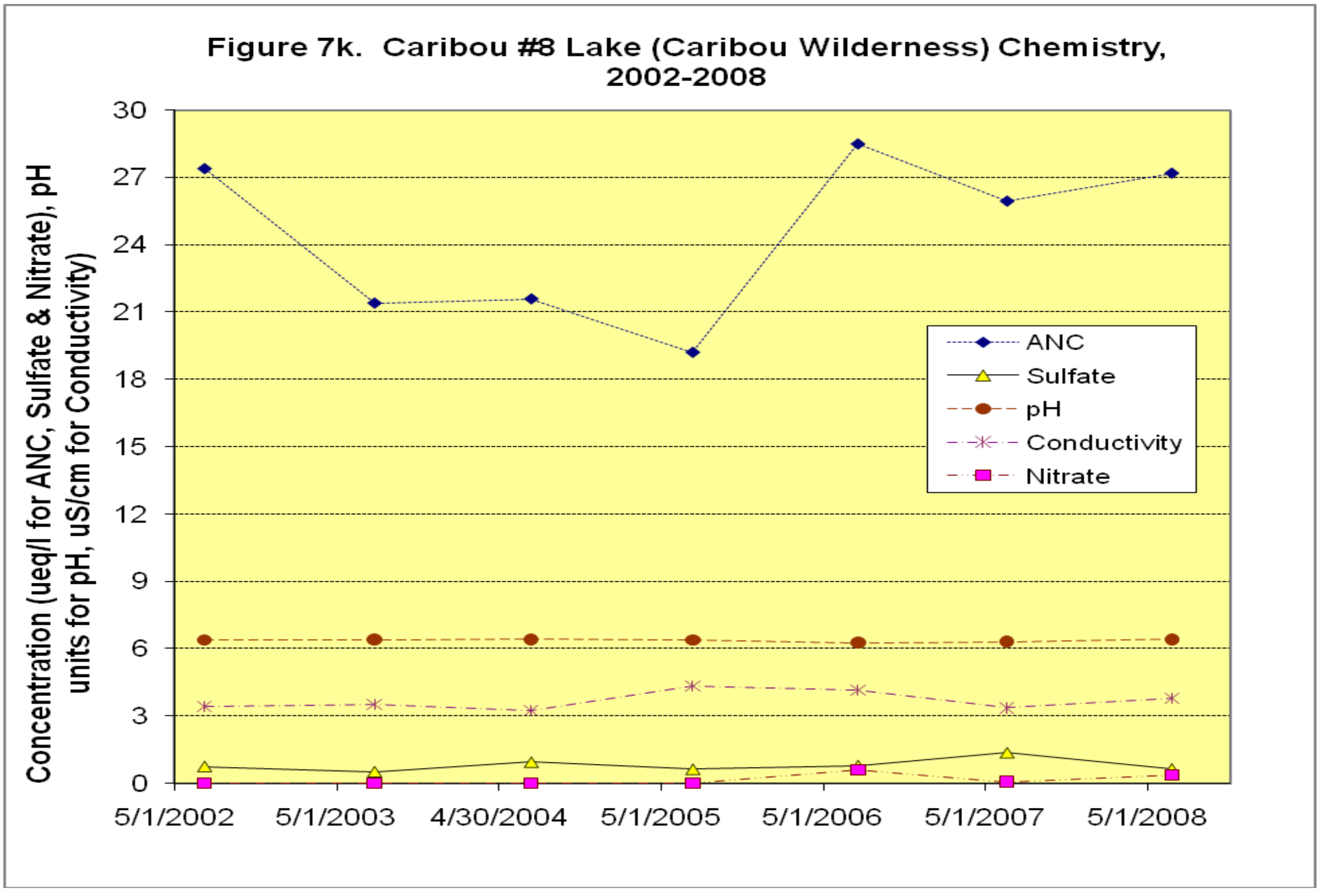


Figure 7k. Caribou #8 Lake (Caribou Wilderness) Chemistry, 2002-2008
Concentration (ueq/l for ANC, Sulfate & Nitrate), pH units for pH, uS/cm for Conductivity)
30
27
24
21
18
15
12
9
6
3
0
5/1/2002
5/1/2003
4/30/2004
5/1/2005
5/1/2006
5/1/2007
5/1/2008
ANC
Sulfate
pH
Conductivity
Nitrate

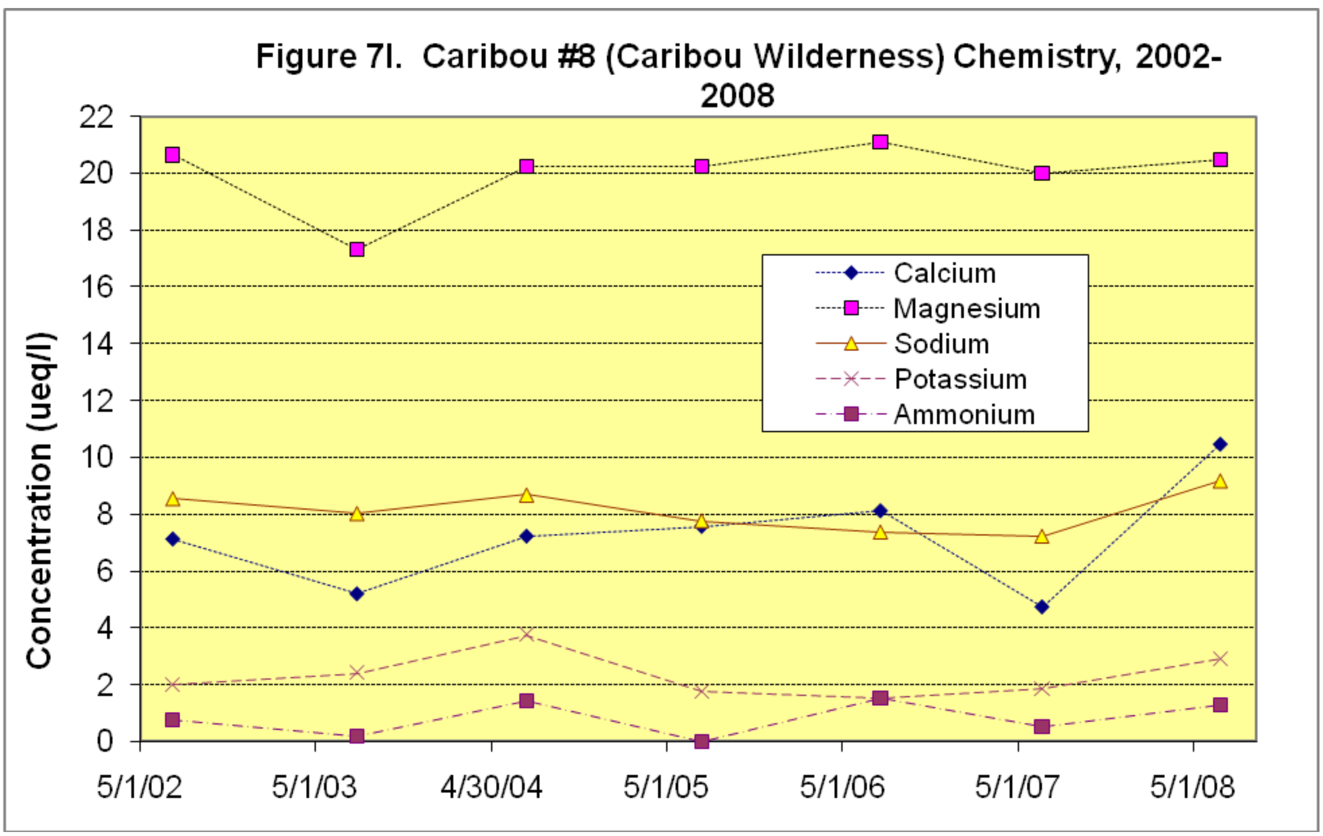


Figure 7l. Caribou #8 (Caribou Wilderness) Chemistry, 2002-2008
Concentration (ueq/l)
22
20
18
16
14
12
10
8
6
4
2
0
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
Calcium
Magnesium
Sodium
Potassium
Ammonium

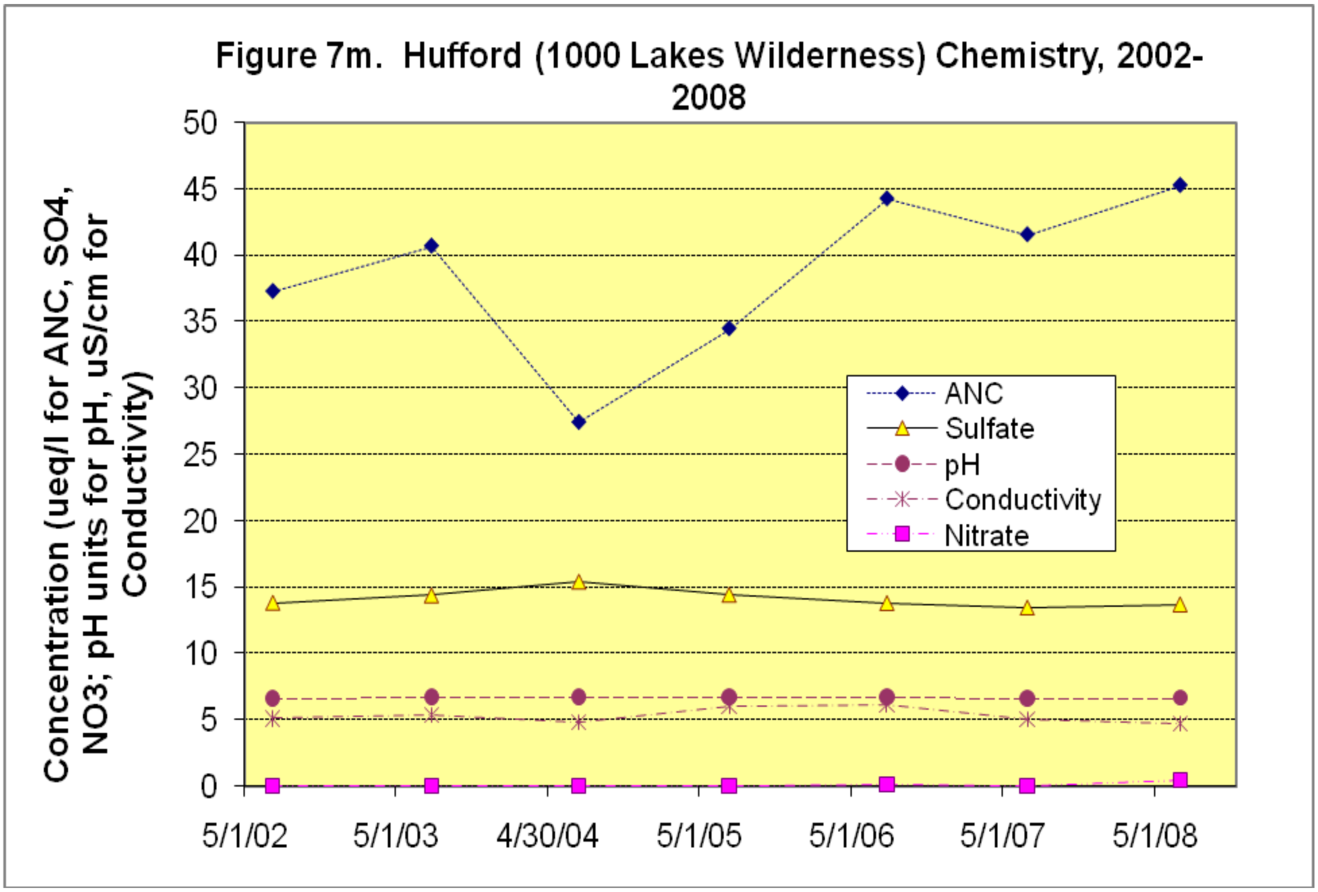


Figure 7m. Hufford (1000 Lakes Wilderness) Chemistry, 2002-2008
Concentration (ueq/l for ANC, SO4, NO3; pH units for pH, uS/cm for Conductivity)
50
45
40
35
30
25
20
15
10
5
0
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
ANC
Sulfate
pH
Conductivity
Nitrate

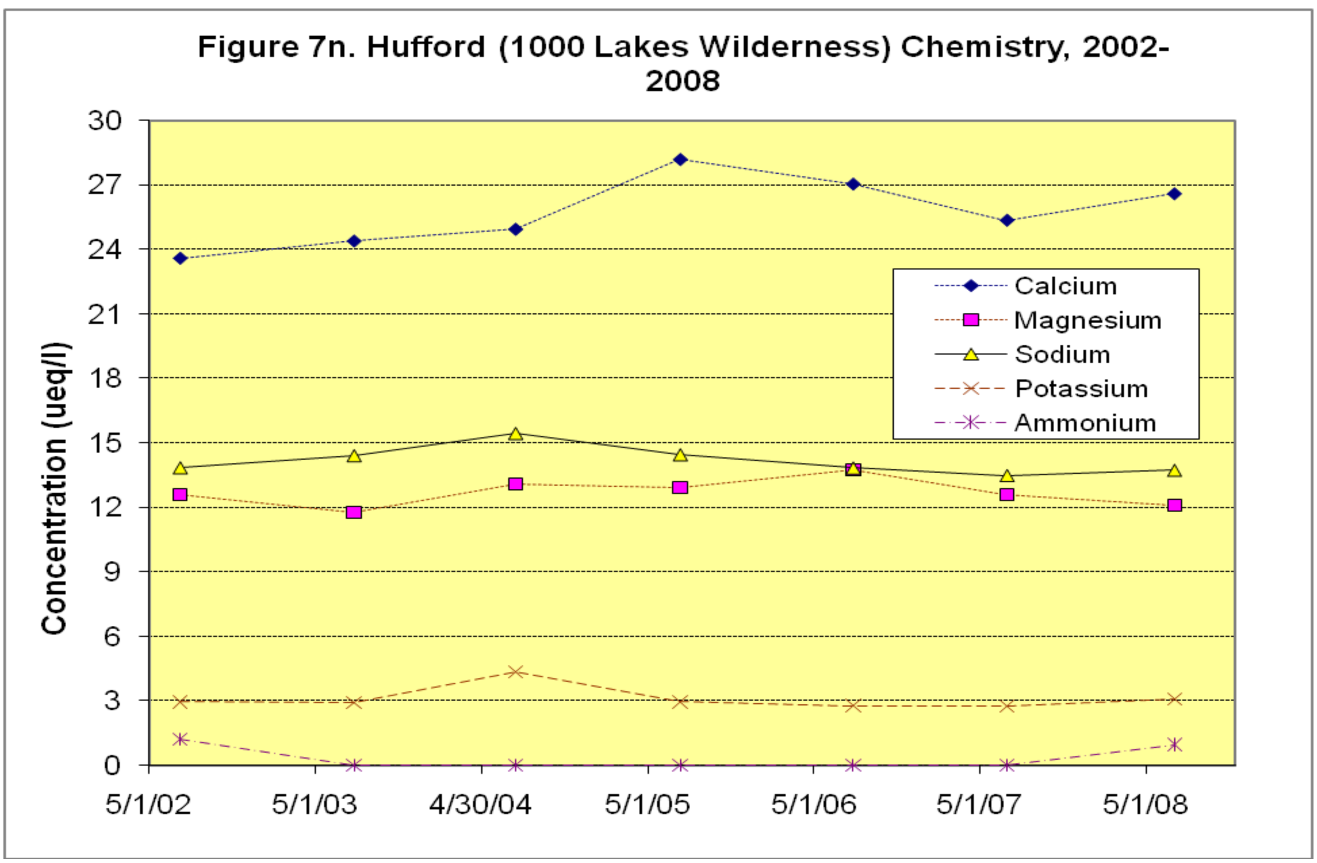



Figure 7n. Hufford (1000 Lakes Wilderness) Chemistry, 2002-2008
Concentration (ueq/l)
30
27
24
21
18
15
12
9
6
3
0
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
Calcium
Magnesium
Sodium
Potassium
Ammonium

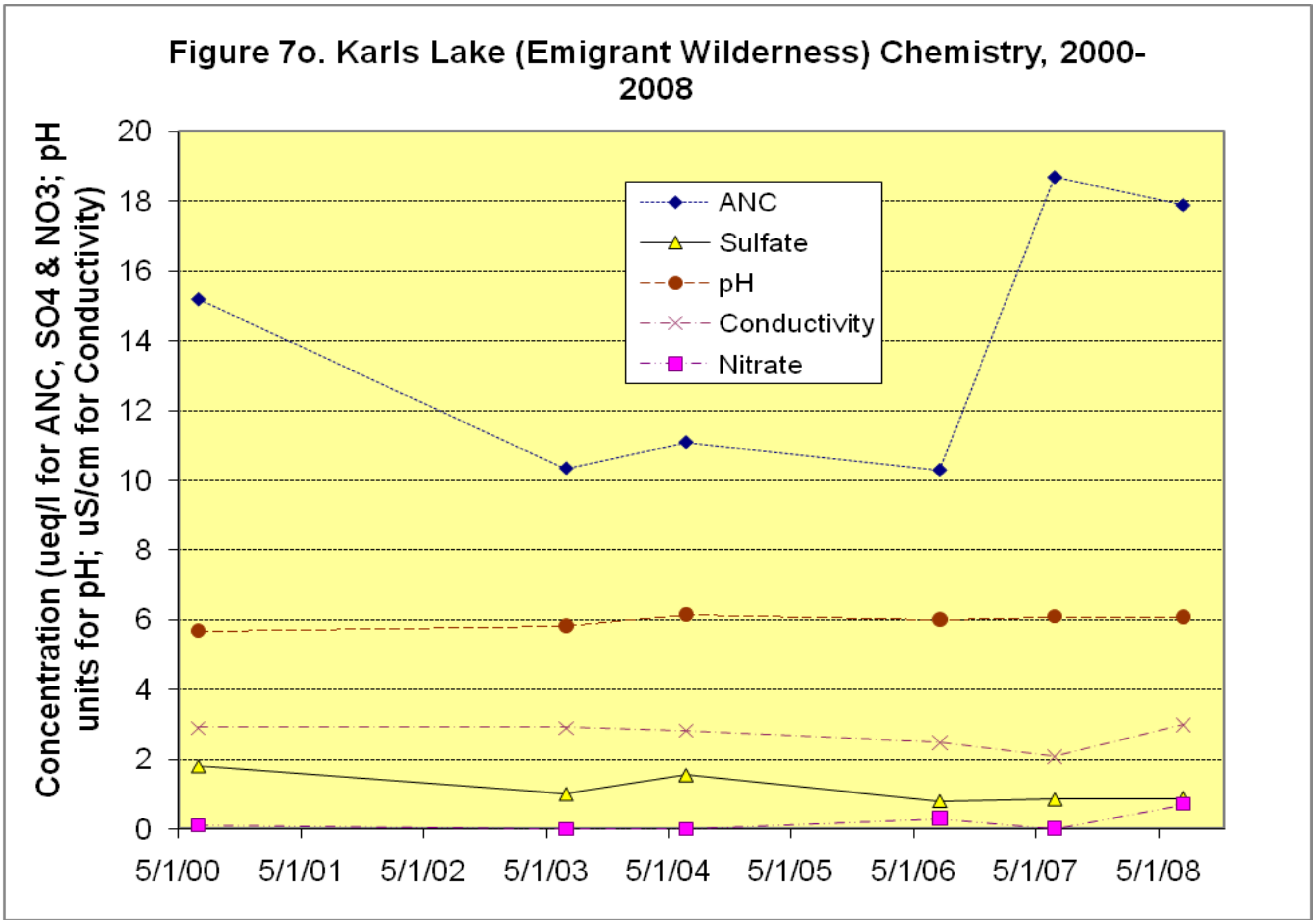


Figure 7o. Karls Lake (Emigrant Wilderness) Chemistry, 2000-2008
Concentration (ueq/l for ANC, SO4 & NO3; pH units for pH; uS/cm for Conductivity)
ANC
Sulfate
pH
Conductivity
Nitrate
0
2
4
6
8
10
12
14
16
18
20
5/1/00
5/1/01
5/1/02
5/1/03
5/1/04
5/1/05
5/1/06
5/1/07
5/1/08

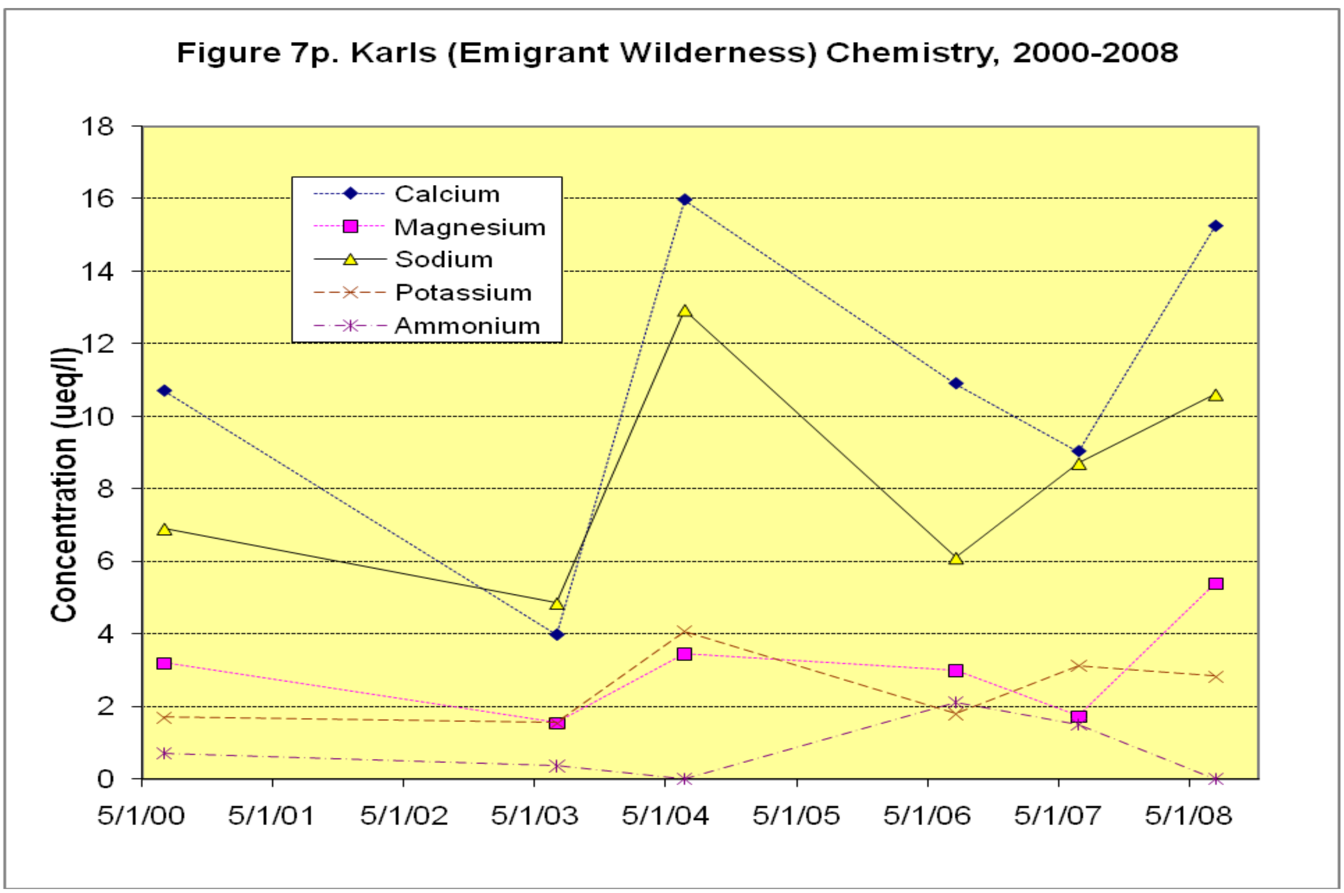



Figure 7p. Karls (Emigrant Wilderness) Chemistry, 2000-2008
Concentration (ueq/l)
Calcium
Magnesium
Sodium
Potassium
Ammonium
0
2
4
6
8
10
12
14
16
18
5/1/00
5/1/01
5/1/02
5/1/03
5/1/04
5/1/05
5/1/06
5/1/07
5/1/08

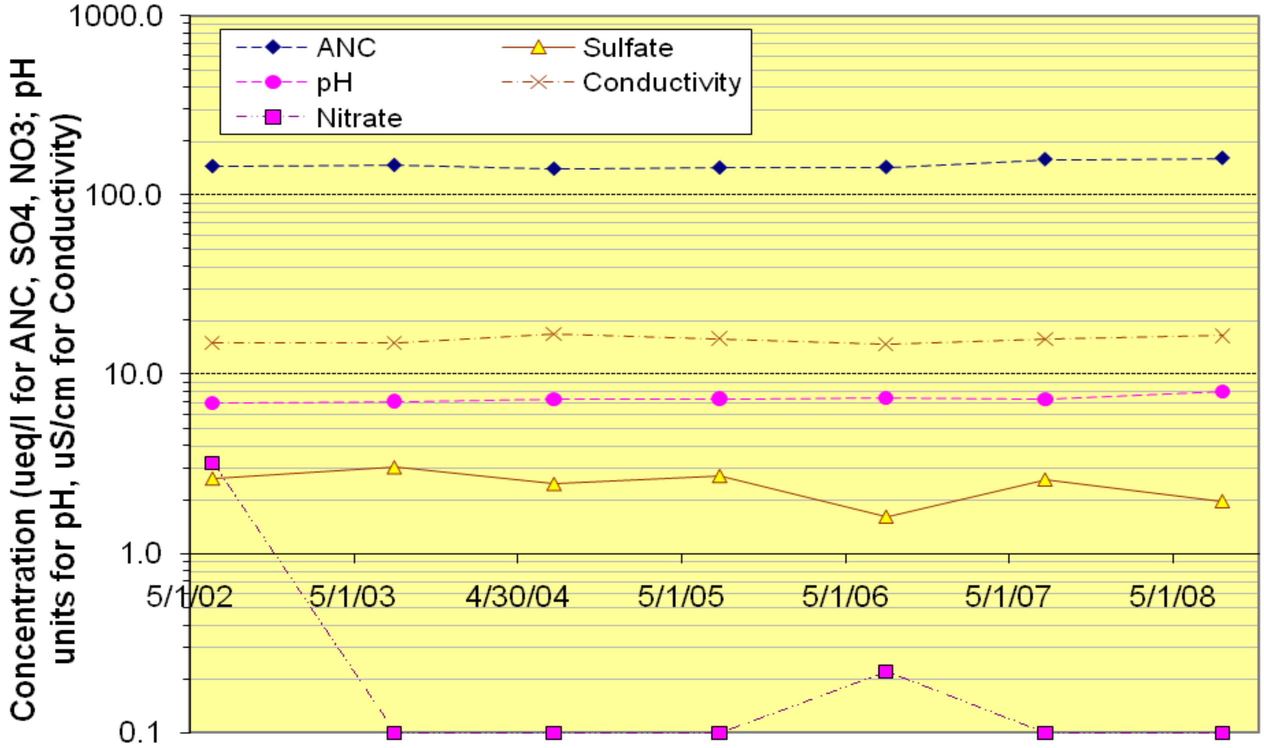



**Figure 7q. Patterson (S Warner Wilderness) Chemistry, 2002-2008 (0.1 values are actually 0)**

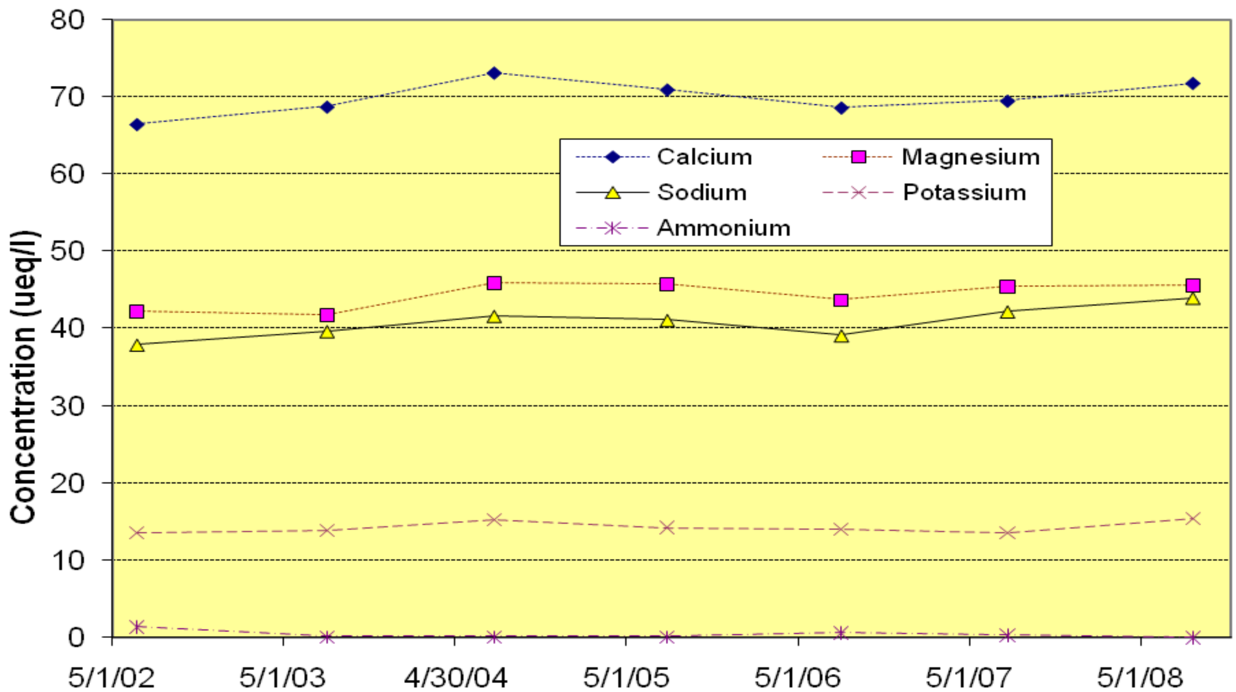



**Figure 7r. Patterson (S Warner Wilderness) Chemistry, 2002-2008**

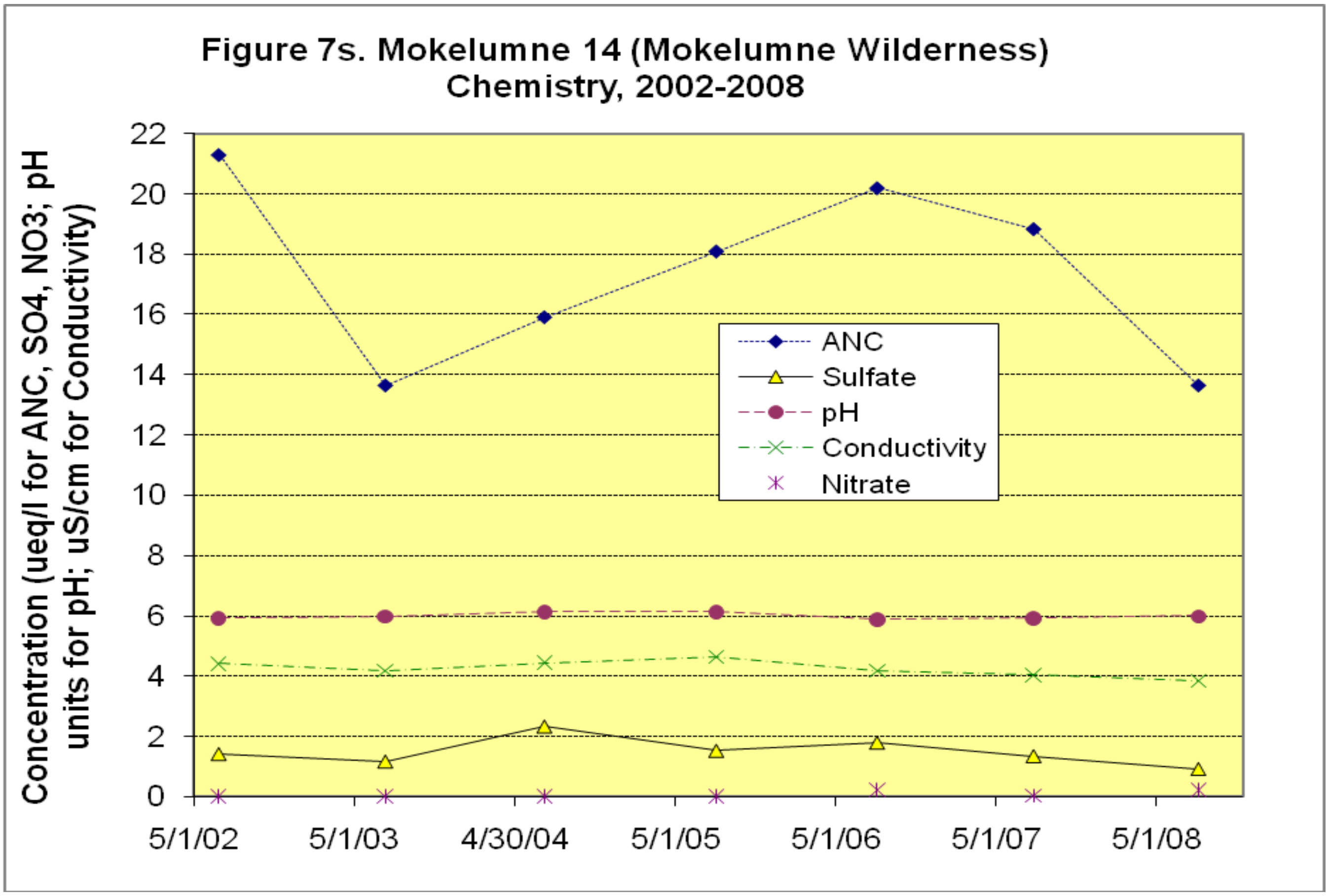


Figure 7s. Mokelumne 14 (Mokelumne Wilderness) Chemistry, 2002-2008
Concentration (ueq/l for ANC, SO4, NO3; pH units for pH; uS/cm for Conductivity)
0
2
4
6
8
10
12
14
16
18
20
22
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
ANC
Sulfate
pH
Conductivity
Nitrate

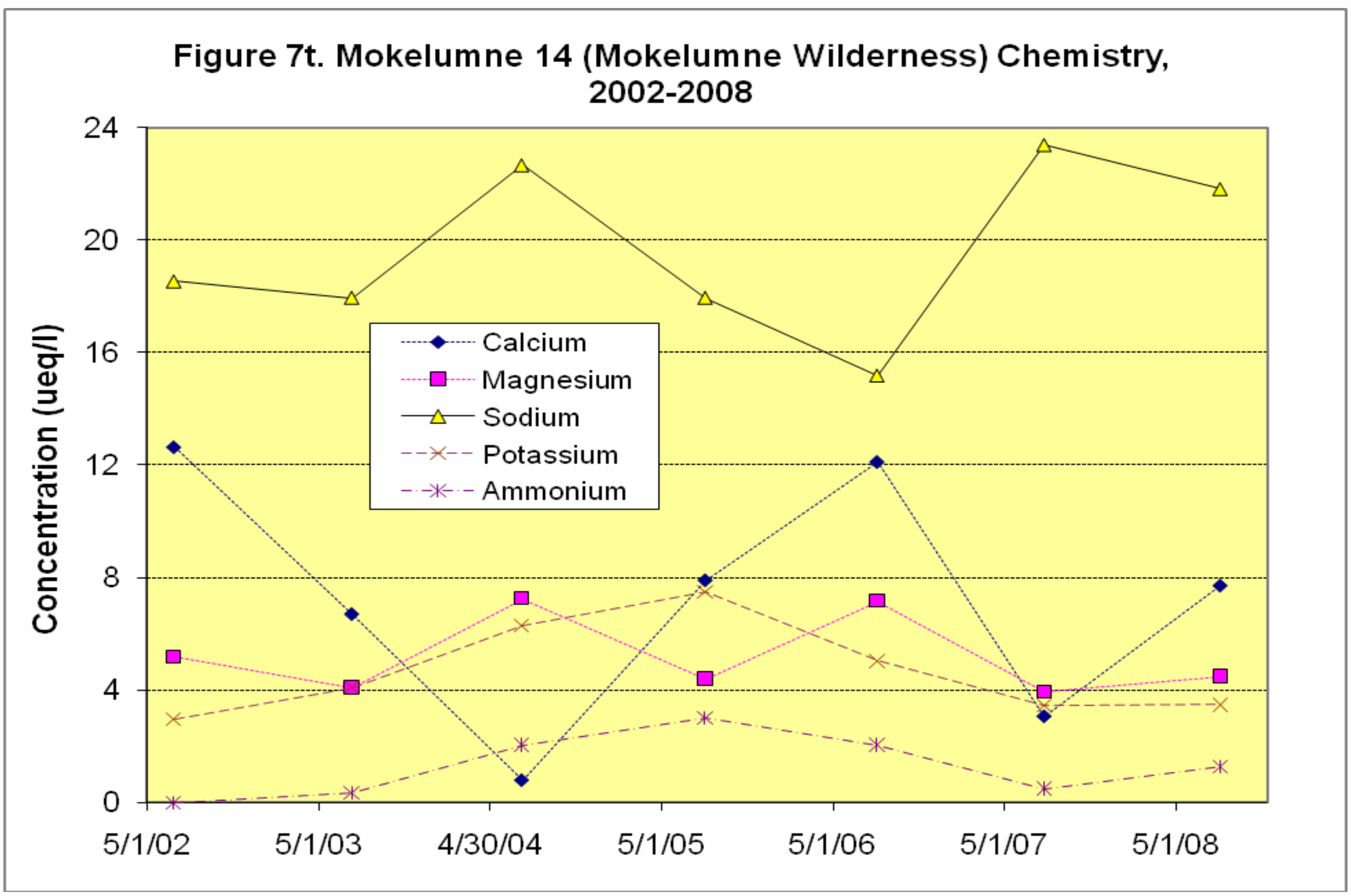


Figure 7t. Mokelumne 14 (Mokelumne Wilderness) Chemistry, 2002-2008
Concentration (ueq/l)
0
4
8
12
16
20
24
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
Calcium
Magnesium
Sodium
Potassium
Ammonium

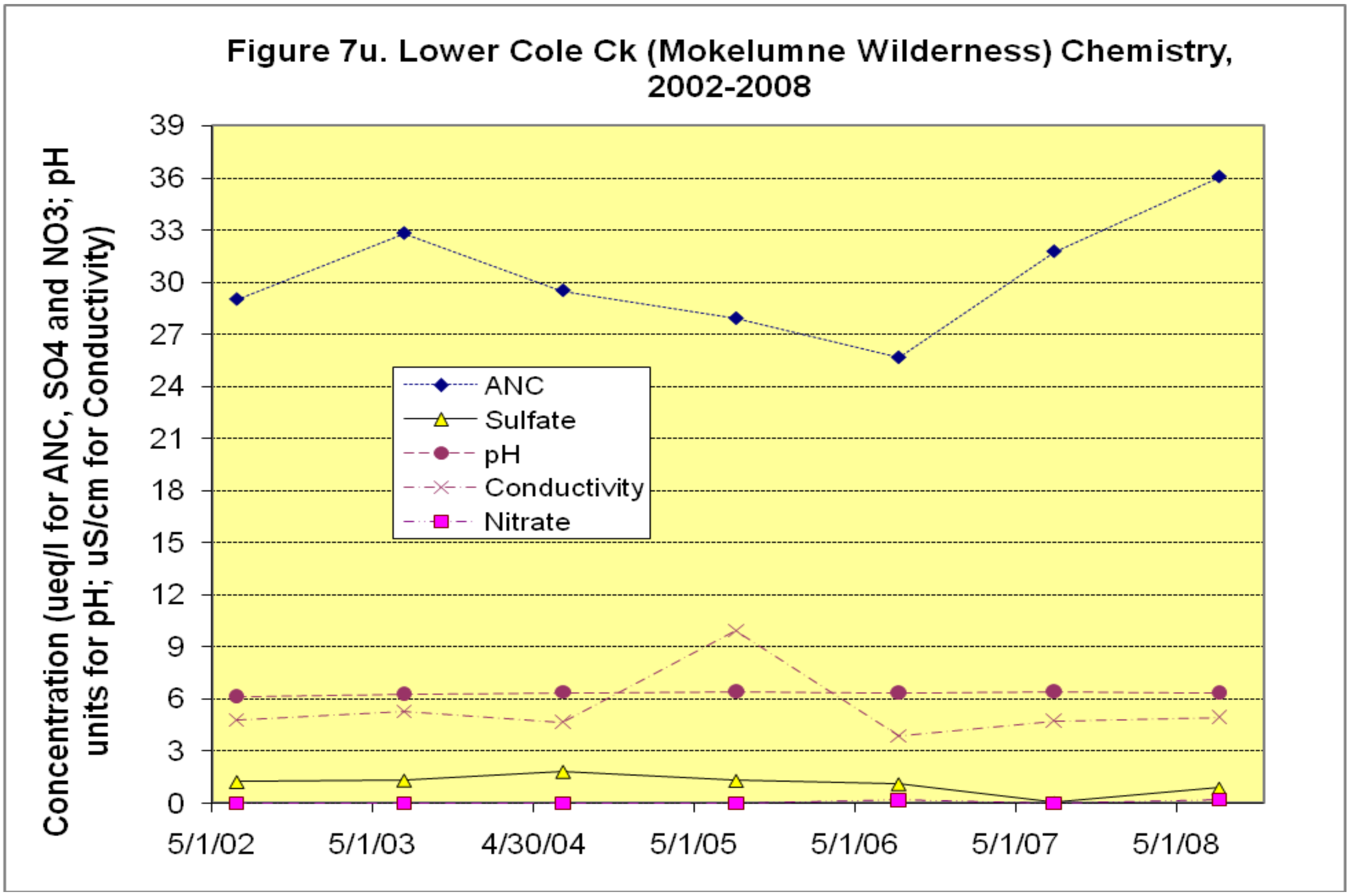


Figure 7u. Lower Cole Ck (Mokelumne Wilderness) Chemistry, 2002-2008
Concentration (ueq/l for ANC, SO4 and NO3; pH units for pH; uS/cm for Conductivity)
39
36
33
30
27
24
21
18
15
12
9
6
3
0
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
ANC
Sulfate
pH
Conductivity
Nitrate

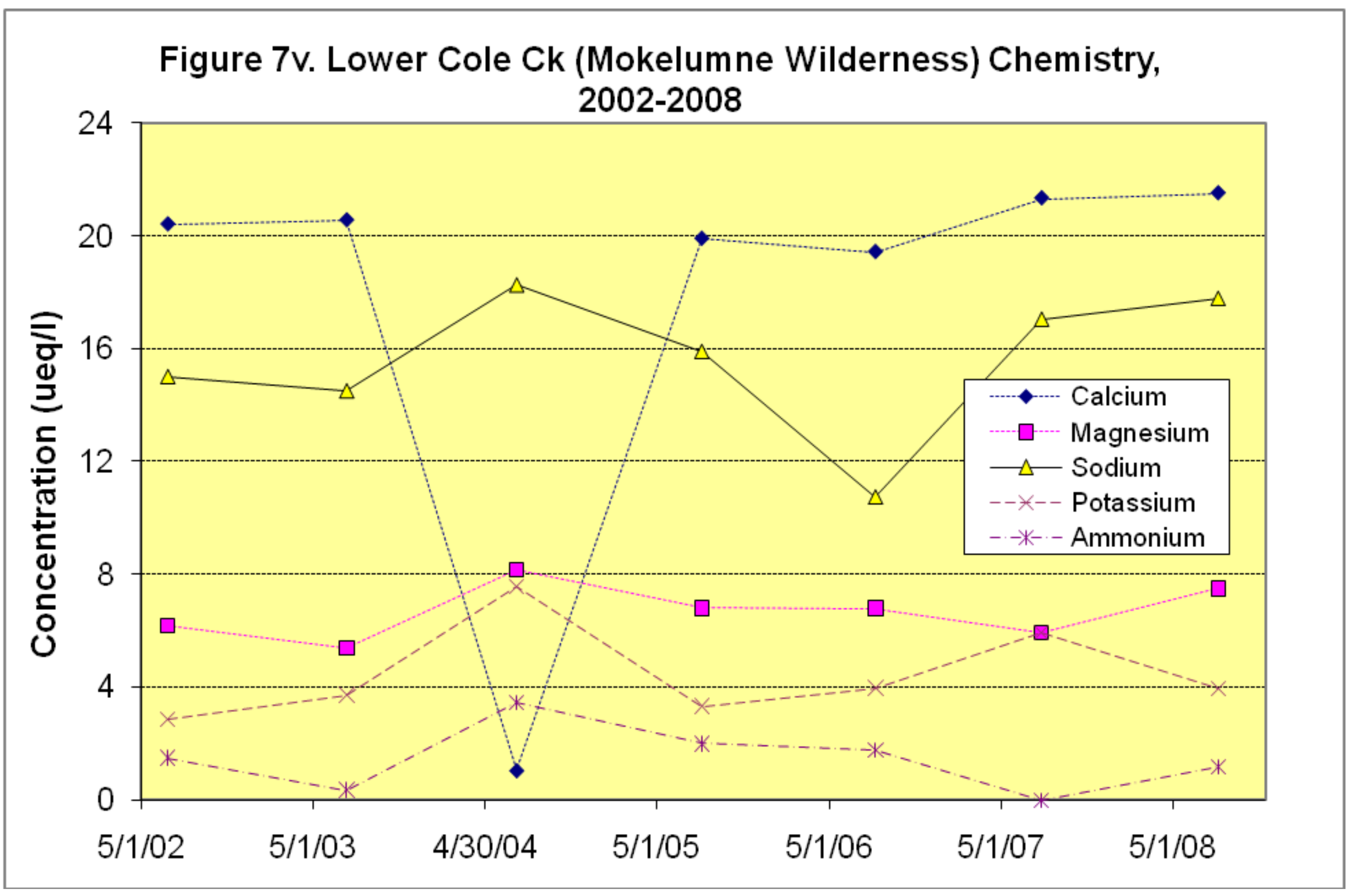


Figure 7v. Lower Cole Ck (Mokelumne Wilderness) Chemistry, 2002-2008
Concentration (ueq/l)
24
20
16
12
8
4
0
5/1/02
5/1/03
4/30/04
5/1/05
5/1/06
5/1/07
5/1/08
Calcium
Magnesium
Sodium
Potassium
Ammonium

The magnitudes of concentration changes between years are typically small, usually much less than one μEq $L^{-1}$ annually. During development of the monitoring component of the Sierra Nevada Framework extensive research identified that annual ANC, sulfate and nitrate changes less than 30% would not be cause for alarm (personal communications, Al Leydecker and Jim Sickman 2000). The sulfate percent changes in Figure 7 are typically less than 30%, even for the low concentrations levels at which very low absolute differences would generate relatively large percentage differences. However, over 80% of the lakes experienced increased ANC from 2007 to 2008, with over 60% of all lakes having the highest ANC on record in 2008. Many of these ANC increases were over the 30% criteria identified by Leydecker and Sickman. The increase in ANC is probably beneficial, and could suggest improved buffering capability on the regional scale although a longer monitoring record is needed to substantiate this speculation. Four lakes had increased nitrate concentrations of at least 30% in 2008 compared to 2007. Reasons for the nitrate increases aren't known, although all four were in the central Sierra, in Desolation and Emigrant Wildernesses where atmospheric pathways could carry elevated levels of nitrogenous species. The magnitude of the nitrate increases is typically small, less than one μEq $L^{-1}$ from 2007 to 2008, and the 2008 nitrate levels were generally within the historical range.

Besides ANC and nitrate, calcium concentrations also increased from 2007 to 2008, with ten of the eleven lakes experiencing increased calcium. At six of the eleven the 2008 calcium concentrations were the largest on record. Increased calcium is generally regarded as positive, at least in terms of potential acidification, because calcium acts as a buffering agent.

The following table summarizes the results of the temporal trend analyses (from the beginning of each record—see table on page 4—through 2008). Normality testing, for each constituent at each location, showed that about 18% of the constituents were not normally distributed. To standardize the trend analyses and to be conservative, non-parametric trend testing was undertaken for all constituents. Hyphenated cells signify a non-significant trend (at $\alpha = 0.10$). Numerical values are the Sen slope estimate (Sen 1968) of significant temporal trends based on the Mann-Kendall test (Gilbert 1987). A negative value signifies a significant downward trend so that, for instance, over the 23-year sampling period at Waca Lake sulfate decreased approximately 0.13 μEq $L^{-1}$ per year.

| **Lake** | **Constituent** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ANC | Ca | $NO^3$ | $SO^4$ | Cl | K | Mg | Na | $NH^4$ | pH |
| Waca | -- | -- | -- | -0.13 | -- | -- | -- | 0.04 | -- | -- |
| Long | -- | 0.97 | -- | -- | -- | -- | -- | -- | -- | -- |
| Powell | 0.94 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Key | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.03 |
| Smith | -- | -- | -- | -0.09 | -- | 0.04 | -- | -- | -- | -- |
| Patterson | -- | -- | 0.08 | -- | 0.07 | -- | -- | 0.84 | -- | 0.10 |
| Mokelumne14 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Lower Cole Ck | -- | -- | 0.04 | -- | -- | -- | -- | -- | -- | -- |
| Hufford | -- | -- | 0.07 | -- | -- | -- | -- | -- | -- | -- |
| Caribou8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Karls | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

The primary long-term trends of practical significance are increases in ANC at Powell Lk, calcium at Long Lk, and sodium at Patterson Lk. In terms of acidification and nitrification, these changes are not detrimental, and in fact suggest the potential for increased buffering of acidic compounds. Some of the other statistically significant changes may be spurious. For instance, constituents like nitrate, typically with very low or non-detectable concentrations, first showed statistically significant trends (e.g., Lower Cole Ck Lk) when laboratory instrumentation was changed and detection limits changed. Also the statistical testing follows a typical convention of assigning one-half of the detection limit value for non-detects. When the detection limit changed a spurious significance could result based largely on the detection limit change.

5.2.1 Waca

**W**aca Lake is located immediately west of the crest of the Sierra Nevada at approximately 2,495 m elevation about 12 km southwest of Lake Tahoe. It is one of many adjacent lakes in the Desolation Valley section of Desolation Wilderness.

Waca is a headwater lake in granodiorite terrain with little vegetation on its watershed. The lake occupies about 2 hectares within a 10-hectare, south-west facing watershed. During surveys between 2002 and 2004, and 2006 to 2008, the maximum water depth at Waca was about 11 m, and a Secchi disk was usually visible at the lake bottom. In autumn 1991 fish were observed in Waca.

Waca Lake has the longest monitoring record in the Region 5 network, now thirteen sample collections, starting with the Western Lake Survey in 1985 (Figures 7a and 7b). A down trend in sulfate, first identified at Waca in 2004, parallels the general trend downward in the atmospheric wet deposition and sulfate concentration recorded at long-term deposition monitoring locations in Yosemite and Sequoia-Kings Canyon National Parks (NADP 2006). At Waca sulfate concentrations in the 4-6+ $\mu Eq\ L^{-1}$ range between 1985 and 1993 have more recently dropped to the 2-3+ range, with the lowest recorded value, 1.7 $\mu Eq\ L^{-1}$ in 2006.

For the first time sodium increased statistically in 2008, although the small rate of change does not suggest that any management action need to be taken. Significant decreases last year in calcium and chloride were not repeated in 2008; in particular the 2008 calcium concentration more than doubled from the 2007 value (Figure 7b).

The 30% change criterion, mentioned above as an indicator of potential concern, is met for ANC. This higher percent change is not believed to foretell acidification because ANC is increasing over time, rather than decreasing as would be expected as a precursor for acidification.

5.2.2 Key

**K**ey Lake, located in the north-central portion of Emigrant Wilderness at 2,799 m elevation and almost due east of San Francisco, drains a west-facing catchment approximately 6 hectares in area. This headwater lake is small, at 1 hectare area. The bedrock geology is similar to much of the Sierra Nevada dominated by felsic materials such as granodiorite, diorite, tonalite and felsic gneiss and schist. There is very little vegetation in the Key Lake watershed. Key Lake is relatively shallow, less than 3 m maximum depth, and during surveys between 2002 and 2007 a Secchi disk was always visible at the lake bottom.

The 2007-2008 ANC difference meets the 30% triggering value, but as with many lakes in 2008 the change was an increase. None of the constituent concentrations plotted in Figure 7c or 7d show an obvious trend through the full monitoring period; increases are typically followed by decreases (or vice versa), and only the pH trend is statistically significant in 2008. Because pH is scaled logarithmically a 10-fold change in hydrogen ion concentration is represented by a one unit change in pH. Consequently plotting of pH on a linear scale masks changes. At Key Lake a statistically significant increase in pH was identified for the first time in 2007, and again in 2008. The change is relatively small, 0.03 pH unit, and not believed to be practically significant.

5.2.3 Long

**L**ong Lake occupies a moderately large (63 ha), north-facing headwater catchment in the northeastern section of Kaiser Wilderness about 75 km northeast of Fresno. At 2,725 m elevation, Long Lake is in the same general elevation range as most of the other lakes assessed for temporal trends. It has more vegetation than many other Sierran wilderness lakes, with about one-half of the granodiorite-dominated catchment in vegetation identifiable from aerial photos. The lake occupies about 3.8 ha area and is backed by a 400-m headwall immediately due south. During surveys between 2002 and 2004, and 2006 to 2008, a Secchi disk was visible about one-half the way to the maximum depth of the lake (14 m).

ANC at Long Lake is higher than at most of the other lakes addressed in this section, and increased substantially from 2007 to 2008 (Figure 7e). The 2008 increase was not, however, large enough to drive a statistical increase through the full monitoring period. The major cations calcium, sodium, magnesium and potassium also increased in 2008, with the calcium increase large enough to sustain a statistically significant increase over the full span of the monitoring program. The yearly calcium increase, 0.97 $\mu Eq\ L^{-1}$, is notable and may portend increased buffering capability at this lake. At Long both calcium and sodium concentrations are also slightly higher than at the other Sierran lakes. Only the ANC increase met the 30% annual change criterion.

5.2.4 Powell

**P**owell Lake drains a north-facing, 32-ha catchment in the western portion of Emigrant Wilderness. This headwater lake is slightly lower down on the western slope of the Sierra than most other lakes in the LAKES network. Powell's area is about 1.6 ha and its elevation is 2,685 m. As with many of the other lakes detailed here, Powell's catchment is dominated by granodiorite. Almost one-half of the catchment is well-vegetated. Between 2002 and 2008 Secchi disk transparency ranged was usually over 6 m and maximum lake depth was about 8 m.

The only statistically significant temporal trend at Powell is almost a one μEq $L^{-1}$ annual increase in ANC. Similar to Long Lake, at Powell there has been very little variation through time in conductivity, magnesium, potassium, ammonium and sulfate (Figures 7g and h). And similar to most monitored lakes nitrate concentrations have been very low, and at Powell were below the detection limit for all five surveys between 2000 and 2005. None of the annual ANC, sulfate or nitrate concentration changes at Powell Lake meet the 30% criterion.

### 5.2.5 Smith

**S**mith Lake, located about 4 km west of Waca Lake at the western edge of Desolation Wilderness, lies in a west-facing catchment with a 300-m headwall immediately east of the lake. This 2,649 m elevation lake occupies about 10% of its 35-ha granite-dominated catchment. Mapping software identifies Smith Lake as dammed. A concern is that chemicals could leach from a dam and confound assessment of atmospheric effects on the lake's chemistry. Field work identifies the dam as a small wooden one that presumably is not influencing lake water chemistry in terms of atmospherically-derived chemical constituents. At 34 m, Smith is the deepest Sierran lake in the LAKES monitoring network. Its transparency between 2006 and 2008 ranged from 9.75 to over 15 m (the Secchi disk measurement in 2007 was limited by a 15-m line length).

Besides Waca Lake, Smith Lake is the only lake with a statistically significant temporal trend for sulfate. As with Waca, the trend is relatively small, down 0.09 μEq $L^{-1}$ $yr^{-1}$. Sulfate concentrations dropped from the 6-8 μEq $L^{-1}$ range in the mid-1980s to the 4-5 μEq $L^{-1}$ range more recently. A minor (0.04 μEq $L^{-1}$ $yr^{-1}$) statistical increase in potassium was identified for the second year running, and to varying degrees, other constituents share visually decreasing and increasing ionic concentration patterns through time (Figures 7i and j). The patterns may be due partly to potentially differing sampling protocols and (or) laboratories analyzing the samples. For instance at Smith Lake in 1985 and 1986 the samples were analyzed by K. McCleneghan, a contract researcher for the California Air Resources Board (McCleneghan et al. 1987), in the early 1990s by the University of California, Santa Barbara, and since then by RM.

A 6 μEq $L^{-1}$ ANC drop in 2007 was not sustained in 2008 (Figure 7i) and although nitrate in 2008 increased more than 30% from 2007, the absolute magnitude of the increase is small, and the 2008 nitrate concentration is still relatively low.

### 5.2.6 Patterson

**C**ompared to other lakes in the monitoring network, Patterson Lake, located about 29 km east southeast of Alturas, is large (8.6 ha) and deep (35 m). At 2,750 m elevation, Patterson Lake sits on volcanic terrain in a 35 ha, northeast-facing catchment 200 m below Warren Pk, on the crest of the Warner Mountains. As one of the few lakes in the South Warner Wilderness, Patterson experiences relatively high recreational use. Paleopollen and charcoal information provides a detailed vegetation and fire record for this lake going back over 12,000 years (Minckley et al. 2007, Minckley 2003). Patterson appears to be less transparent than most of the Sierran lakes surveyed, with a Secchi disk visible to between 1.5 & 4.25 m depth in 2002, 2004, 2006 and 2007.

Probably because it sits on volcanic terrain—and may receive atmospheric inputs from the Great Basin to the east--the chemistry of Patterson Lake (Figures 7q and r) differs appreciably from lakes being monitored in the Sierra Nevada. ANC for instance, has been between 140 and 160 μEq $L^{-1}$ during all years monitored, a range that is much higher than any lakes currently monitored in the Sierra Nevada. Ammonium and nitrate concentrations are low, however, at Patterson, similar to most Sierran lakes.

The relatively high ANC concentrations and the low nitrate concentrations at Patterson suggest little current concern for potential acidification or nutrient issues. A minor increase in pH identified as statistically significant in 2007 persisted into 2008. In 2008 also statistically significant increases occurred for nitrate, chloride and sodium. The nitrate and

chloride increases were minor (less than one $\mu$Eq $L^{-1}$), but sodium has increased at over 0.8 $\mu$Eq $L^{-1}$ $yr^{-1}$ since monitoring began in 2002. ANC, sulfate and nitrate changes did not reach the 30% criterion between 2007 and 2008.

### 5.2.7 Mokelumne 14

**M**okelumne 14 is a headwater lake at 2,545 m elevation near the northwest border of Mokelumne Wilderness, about 66 km east-southeast of Placerville and 11 km southwest of Carson Pass. Mokelumne 14 is shallow, with a maximum depth of about 2.5 m, and was transparent to the bottom during surveys in 2003-2004 and 2006-2008. Mokelumne 14 has typically had ANC concentrations between 14 and 21 $\mu$Eq $L^{-1}$, undetectable nitrate, and sulfate concentrations below 2 $\mu$Eq $L^{-1}$ (Figure 7s). The south-facing catchment of this 1-ha lake occupies about 45 ha on granodioritic terrain. About two-thirds of the catchment is vegetated and between 2002 and 2004 Secchi disk transparency was to the bottom of the lake. No temporal changes were identified for any chemical constituent for Mokelumne 14 between 2002 and 2008 and the chemistry of this lake approximates that of most other Sierran lakes in the monitoring network (Figure 7).

An ANC drop of 5 $\mu$Eq $L^{-1}$ from 2007 is the largest ANC drop in 2008 of any monitored lake. This drop is larger than 30% and warrants close attention to the chemistry of Mokelumne 14 in 2009.

### 5.2.8 Lower Cole Creek

**L**ower Cole Ck is a 6-m deep, 1-ha lake located at 2,435 m elevation near the northwest border of Mokelumne Wilderness, about 15 km southwest of Carson Pass. Lower Cole Ck lays in a northwest-facing, 46-ha catchment that maxes out in elevation only about 15 m above lake level. Lower Cole differs from most other lakes in the monitoring network in being the third in a chain of lakes. The two lakes above Lower Cole Ck Lk are equal in area or smaller than Lower Cole Ck. Catchment geology is similar to most of the other Sierra Nevada monitoring lakes, with a preponderance of felsic bedrock. About 80% of the lake catchment is vegetated. Between 2003 and 2007 Secchi disk transparency at Lower Cole Ck decreased from over 5 m (to bottom) to less than 4 m.

ANC is relatively high for Lower Cole Ck Lake, compared to other lakes in the LAKES network, and was in the 25 to 33 $\mu$Eq $L^{-1}$ range between 2002 and 2007. As with many of the other lakes, in 2008 ANC increased at Lower Cole Ck, to the highest on record (36 $\mu$Eq $L^{-1}$). Sulfate and nitrate concentrations have been low at Lower Cole Ck, and suggest no imminent concern for either acidification or nutrients. For the first time, in 2008 a statistical trend was identified for nitrate but the slope of the trend line is low (0.03 $\mu$Eq $L^{-1}$ $yr^{-1}$) (Figures 7u and v).

### 5.2.9 Hufford

**H**ufford Lake occupies a 29-ha, north-facing catchment near the center of Thousand Lakes Wilderness in the southern Cascades. The lake itself occupies about 2.6 ha at 2,056 m elevation, below a 2,180 m ridge about 69 km west of Redding. Between 2003 and 2007 Secchi disk transparency was usually to 8+ m, the maximum lake depth. This lake also is not a headwater lake and sits 0.2 km below a smaller lake. Volcanic bedrock dominates this Wilderness and because of the small size of the Wilderness the fewer than ten perennial lakes in the Wilderness receive significant recreational use.

During the seven-year monitoring period ANC has ranged from 28 to 45 $\mu$Eq $L^{-1}$, somewhat higher than for lakes in the central and southern Sierra Nevada (Figure 7m). Similarly, sulfate, calcium, sodium and magnesium concentrations have been relatively high (Figures 7m and 7n). A minor (0.07 $\mu$Eq $L^{-1}$) statistically significant increase in nitrate was identified for the first time in 2008. Changes in ANC, sulfate and nitrate concentrations did not reach the 30% criterion in 2008.

### 5.2.10 Caribou 8

**A**t 2,131 m elevation, Caribou8 Lake lies in the southern third of Caribou Wilderness, about 14 km north of Lake Almanor and 48 km west northwest of Susanville. The lake is about 1 ha in area within an east-facing catchment of 32 ha area. In surveys from 2003 to 2007 Caribou8 was always transparent to the bottom of its 3 m maximum depth. About three-quarters of the terrain in the Wilderness at the elevation of Caribou8 is a blanket of lodgepole pine and red fir.

ANC at Caribou8 has typically been in the mid-20 $\mu$Eq $L^{-1}$ range (Figure 7k), with no recent single year change meeting the 30% threshold. Compared to other lakes in the R5 monitoring network, Caribou8 has relatively high concentrations of magnesium—atypically higher than calcium concentrations—and relatively low sodium concentrations. These differences may be due to the preponderance of volcanic terrain in the Wilderness. A significant temporal downtrend for sodium identified in 2007 was not repeated in 2008, when sodium concentration was the highest on record (Figure 7l). No other statistically significant temporal trends were identified in 2008 and 2008 changes in nitrate or sulfate did not reach the 30% criterion.

#### 5.2.11 Karls

**K**arls Lake occupies a moderately large (74 ha), south-facing headwater catchment in the south-central section of Emigrant Wilderness about 240 km east-northeast of San Francisco. At 2,528 m elevation, Karls Lake is in the same general elevation range as most of the other lakes assessed for temporal trends. About one-quarter of the granodiorite-dominated catchment is vegetation identifiable from aerial photos. The lake occupies about 8.6 ha area and is backed by a 75-m headwall immediately north and northwest. During surveys in 2003, 2004, 2006 and 2007, Secchi disk transparency was usually down to the maximum depth of the lake (5 m).

The water chemistry of Karls Lake is typical of other dilute lakes in the higher elevations of the Sierra Nevada. ANC is low, at 19 $\mu$Eq $L^{-1}$ or less during all sample collections. pH has hovered about 6.0, and nitrate and sulfate have been low or below detection at all sample collections. The 30% change criterion was not met in 2008 by ANC, sulfate or nitrate. No statistically significant temporal trends were identified for any constituent as of 2008.

### 5.3 Lake Transparency

**B**uild-up of nutrients, sediment and other materials reduce water clarity and can promote a proliferation of plant life, often algae, which reduces dissolved oxygen content and often causes the extinction of other organisms (i.e. eutrophication). Lake clarity is an indirect index of the trophic state of a lake and is a good indicator of potential eutrophication. Most high-elevation Wilderness lakes are presumed to have good clarity and not to be eutrophied. Probably the most easily explainable component of water quality change is a reduction over time in water transparency, as measured by a Secchi disk. The disk is lowered into the water and the depth of disk disappearance is the basic measurement. Measurements are subject to individual eyesight problems, glare on the water, waves, and potentially other factors.

Transparency measurements at Lake Tahoe go back to the 1960s. This record is the longest transparency record for Sierra Nevada lakes, and although they probably exist, no repeated monitoring of transparency at other Sierra Nevada high-elevation lakes was identified during a web search (however, the Western Lake Survey completed a "slice-in-time" transparency survey in 1985). At Lake Tahoe, mean year-to-year transparency differences of up to 3 m are evident, along with within-year standard deviations in transparency typically ranging from 2 to 4 m (Elliott-Fisk et al. 1997). Although Lake Tahoe is not the best analogue for the much smaller and shallower lakes monitored in the Forest Service program, it provides the best available information on year-to-year variability. At Lake Tahoe a long-term decline in transparency of about 30 cm $yr^{-1}$ declined from 2001 through 2008 to a several centimeters per year (Rieman and Birzell 2009).

Although atmospheric deposition is identified as a major contributor to reduced clarity in Lake Tahoe—particularly for nitrogen but also for phosphorous and fine sediment--some temporal changes in clarity may be driven by differences in annual precipitation as it drives pollutant loading (Lahontan Water Board 2007).

Transparency data have been collected at 22 Wilderness lakes since 2002 for at least 2 years. At five of the lakes transparency measurements have been made for 6 years. Even the 6-year time period is too short to allow determination of trends through time (for instance, a monitoring program for Lake Superior describes a 5-yr Secchi disk dataset as being of "marginal usefulness" for trend determination, with a 10-15 yr dataset constituting "a valuable dataset"--http://www.epa.gov/glnpo/lakesuperior/epo1998.pdf accessed 12/29/04). Similarly, a study of transparency of Minnesota lakes identified 8-10 yrs as needed to detect a 10% change in transparency (http://www.pca.state.mn.us/water/pubs/lar-fleming.pdf accessed 12/29/04).

Although our transparency dataset is too short for determination of time trends, some preliminary results can be seen (Figure 8):

- Transparencies ranged from 1.5 to 15 m between 2002 and 2008.
- For fifteen of the 22 lakes monitored (Lower Cole Ck, Mokelumne14, Waca, Caribou8, Hufford, Karls, Key, Little East Marie, Cascade, Treasure, Bench, Walton, Bullfrog, Vermillion and E Wahoo), the lake bottom was usually observed, thereby “limiting” the Secchi disk depth. The transparency depths for these lakes are potentially unrealistically low because they are bounded by shallow lake depth.
- In most of the lakes transparency change from year to year was very small, less than one-half m. Exceptions include Smith, Dana and Moat Lakes where single year changes ranged to over 5 m. Reasons for these atypically large annual changes are unknown; and more data are needed to substantiate these single-year changes.
- In 2003 and 2004 the transparency of Patterson Lake in South Warner Wilderness, at < 1.75 m, was the lowest of the lakes monitored. More recently, transparency at Patterson has increased, but as of 2008 it still had the second-lowest value. Coincidentally, Patterson is the deepest lake currently being monitored (at 35 m depth). This lake's chemistry has also historically diverged from the other lakes. For instance, its ANC was 143 $\mu Eq\ L^{-1}$ this year, over 3 fold above the lake with the next highest ANC. Patterson’s low transparency is another piece of evidence suggesting that the physio-chemical dynamics of Patterson differs from that of lakes in the Sierra Nevada.
- Forty-seven lakes in Wildernesses currently monitored were assessed for Secchi transparency in the 1985 Western Lake Survey. The range in the Western Lake Survey transparency (1.5-27.75 m) incorporates the range for the lakes currently monitored (1.5-15) implying that the current transparency measurements are not grossly inaccurate.

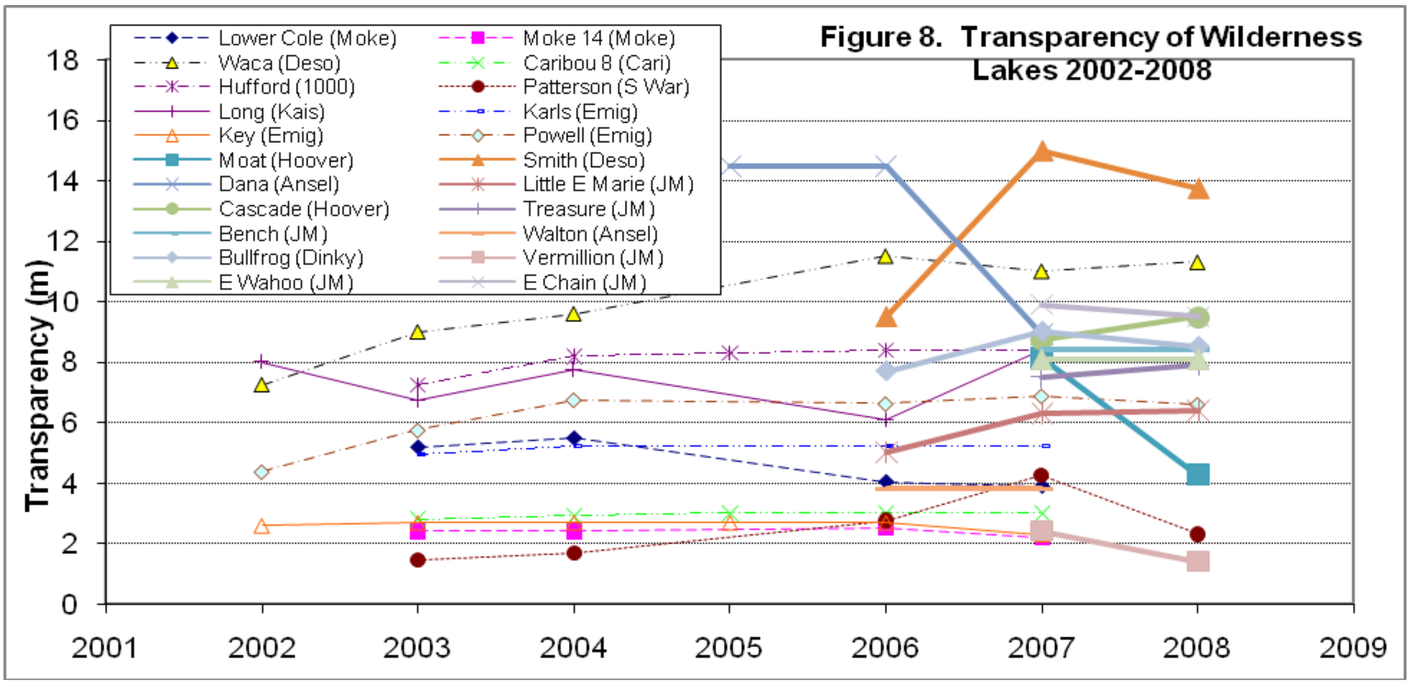


**Figure 8. Transparency of Wilderness Lakes 2002-2008**

## 6.0 Conclusions

Completion of the network of long-term monitoring lakes in 2007 should reduce the expense of monitoring and extend the ability to identify temporal and spatial trends in lake chemistry changes at twelve Wildernesses—and 25 lakes--in the Sierra Nevada and northeastern California.

The 2008 lake monitoring identified no evidence of acidification or nutrification, from either water chemistry or water transparency analyses. In contrast, 2008 measurements at most lakes showed increased acid neutralizing capacity compared to 2007 measurements.

Eleven lakes were assessed for temporal trends in their acid-base chemistry. Although statistically significant changes in lake chemistry were identified at eight lakes, the changes were generally small and not associated with acidification or nutrient buildup. Exceptions included increases in ANC, calcium and sodium of nearly 1 $\mu Eq\ L^{-1}\ yr^{-1}$ each at three lakes. These increases could indicate increased acid buffering capacity. Statistically significant sulfate decreases at the two

lakes with the longest records may reflect documented reductions in sulfur deposition in many locations in the United States. These trend results are preliminary for most of the lakes and could change as more data are collected.

Lake transparency, or clarity, can be a useful indicator of eutrophication. The transparency record is too short for meaningful statistical analysis. Nevertheless there's no obvious indication that transparency is changing through time or that transparencies are particularly low. Most lakes were transparent to their bottoms in 2008. One lake, Patterson in South Warner Wilderness (Modoc County) is conspicuous in both it's low transparency and chemistry that are atypical of the lakes monitored in the Sierra Nevada. Because of differing geology, atmospheric dynamics and other factors between South Warner and the Sierran wildernesses, the differences in Patterson chemistry and transparency are not interpreted to be a cause for concern.

The overall quality of the 2008 laboratory analysis was slightly above "average" compared to prior years. In some prior years minor irregularities were identified. In 2008 there were none. Continued vigilance in field sample collection and laboratory procedures is recommended to help assure continued high quality data.

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**Appendix I. 2008 Chemistry Results from USDA Forest Service Region 5 Air Program Wilderness Lake Monitoring**

E = epilimnion, H = hypolimnion, FB – field blank, S = shoreline

| Lab ID# | Field ID# | SAMPLE ID | WILDERNESS | MILITARY TIME | SAMPLE DATE | RECEIVE DATE |
|---|---|---|---|---|---|---|
| 08ST3100 | 15DL015-E1 | Bullfrog Lake | Dinky Lakes | 1523 | 06/09/08 | 06/11/08 |
| 08ST3102 | 15DL015-H1 | Bullfrog Lake | Dinky Lakes | 1542 | 06/09/08 | 06/11/08 |
| 08ST3101 | 15DL015-E2 | Bullfrog Lake | Dinky Lakes | 1528 | 06/09/08 | 06/12/08 |
| 08ST3103 | 15DL015-H2 | Bullfrog Lake | Dinky Lakes | 1552 | 06/09/08 | 06/12/08 |
| 08ST3104 | 15KA09-E1 | Long Lake | Kaiser | 1241 | 06/12/08 | 06/17/08 |
| 08ST3106 | 15KA09-H1 | Long Lake | Kaiser | 1255 | 06/12/08 | 06/17/08 |
| 08ST3108 | 15KA09-S1 | Long Lake | Kaiser | 1357 | 06/12/08 | 06/17/08 |
| 08ST3110 | 15KA09-FB | Long Lake | Kaiser | 1301 | 06/12/08 | 06/17/08 |
| 08ST3105 | 15KA09-E2 | Long Lake | Kaiser | 1246 | 06/12/08 | 06/18/08 |
| 08ST3107 | 15KA09-H2 | Long Lake | Kaiser | 1301 | 06/12/08 | 06/18/08 |
| 08ST3109 | 15KA09-S2 | Long Lake | Kaiser | 1401 | 06/12/08 | 06/18/08 |
| 08ST3111 | 15JM345-E1 | East Chain Lake | John Muir | 1413 | 06/17/08 | 06/19/08 |
| 08ST3113 | 15JM345-H1 | East Chain Lake | John Muir | 1425 | 06/17/08 | 06/19/08 |
| 08ST3112 | 15JM345-E2 | East Chain Lake | John Muir | 1417 | 06/17/08 | 06/20/08 |
| 08ST3114 | 15JM345-H2 | East Chain Lake | John Muir | 1433 | 06/17/08 | 06/20/08 |
| 08ST3180 | 16EM47-1E | Powell Lake (midlake) | Emigrant | 1146 | 06/20/08 | 06/24/08 |
| 08ST3181 | 16EM47-2E | Powell Lake (midlake) | Emigrant | 1148 | 06/20/08 | 06/24/08 |
| 08ST3182 | 16EM47-1H | Powell Lake (midlake) | Emigrant | 1159 | 06/20/08 | 06/24/08 |
| 08ST3183 | 16EM47-2H | Powell Lake (midlake) | Emigrant | 1203 | 06/20/08 | 06/24/08 |
| 08ST3184 | 16EM47-1S | Powell Lake (shoreline) | Emigrant | 1303 | 06/20/08 | 06/24/08 |
| 08ST3185 | 16EM47-2S | Powell Lake (shoreline) | Emigrant | 1305 | 06/20/08 | 06/24/08 |
| 08ST3060 | 06CB06-1E | Caribou #8 | Caribou | 1300 | 06/25/08 | 06/27/08 |
| 08ST3062 | 06CB06-FB | Caribou #8 | Caribou | | 06/25/08 | 06/27/08 |
| 08ST3020 | 17HO004-1S | Moat Lake shoreline | Hoover | 1015 | 06/23/08 | 06/27/08 |
| 08ST3021 | 17HO004-WS | Moat Lake shoreline Duplicate | Hoover | 1017 | 06/23/08 | 06/27/08 |
| 08ST3022 | 17HO004-2E | Moat Lake epilimnion | Hoover | 1102 | 06/23/08 | 06/27/08 |
| 08ST3023 | 17HO004-1E | Moat Lake epilimnion Duplicate | Hoover | 1108 | 06/23/08 | 06/27/08 |
| 08ST3061 | 06CB08-2E | Caribou #8 (Surface) | Caribou | 1300 | 06/25/08 | 07/01/08 |
| 08ST3115 | 15JM037-E1 | Vermilion Lake | John Muir | 1353 | 06/26/08 | 07/01/08 |
| 08ST3116 | 15JM037-E2 | Vermilion Lake | John Muir | 1357 | 06/26/08 | 07/03/08 |
| 08ST3117 | 15AA090-S1 | Walton Lake | Ansel Adams | 1355 | 07/01/08 | 07/03/08 |
| 08ST3063 | 06TL06-1E | Hufford Lake | Thousand Lakes | 1430 | 07/01/08 | 07/03/08 |
| 08ST3065 | 06TL06-FB | Hufford Lake Field Blank | Thousand Lakes | | 07/01/08 | 07/03/08 |
| 08ST3040 | 04JM024-FB | Treasure Lake SE | John Muir | | 07/01/08 | 07/03/08 |
| 08ST3041 | 04JM024-1S | Treasure Lake SE | John Muir | 1231 | 07/01/08 | 07/03/08 |
| 08ST3042 | 04JM024-2S | Treasure Lake SE | John Muir | 1235 | 07/01/08 | 07/03/08 |
| 08ST3043 | 04JM024-1E | Treasure Lake SE | John Muir | 1359 | 07/01/08 | 07/03/08 |
| 08ST3044 | 04JM024-2E | Treasure Lake SE | John Muir | 1353 | 07/01/08 | 07/03/08 |
| 08ST3064 | 06TL06-2E | Hufford Lake Duplicate | Thousand Lakes | 1445 | 07/01/08 | 07/08/08 |
| 08ST3118 | 15AA090-S2 | Walton Lake | Ansel Adams | 1401 | 07/01/08 | 07/08/08 |
| 08ST3045 | 04HO40-1S | Cascade Lake | Hoover | 1100 | 07/06/08 | 07/08/08 |
| 08ST3046 | 04HO40-2S | Cascade Lake | Hoover | 1103 | 07/06/08 | 07/08/08 |
| 08ST3047 | 04HO40-1E | Cascade Lake | Hoover | 1231 | 07/06/08 | 07/08/08 |
| 08ST3048 | 04HO40-2E | Cascade Lake | Hoover | 1238 | 07/06/08 | 07/08/08 |
| 08ST3000 | 03DE02-E1 | Smith Lake | Desolation | 1452 | 07/09/08 | 07/11/08 |
| 08ST3001 | 03DE02-E2 | Smith Lake | Desolation | 1454 | 07/09/08 | 07/11/08 |
| 08ST3002 | 03DE02-H1 | Smith Lake | Desolation | 1506 | 07/09/08 | 07/11/08 |

| Lab ID# | Field ID# | SAMPLE ID | WILDERNESS | MILITARY TIME | SAMPLE DATE | RECEIVE DATE |
|---|---|---|---|---|---|---|
| 08ST3003 | 03DE02-H2 | Smith Lake | Desolation WA | 1508 | 07/09/08 | 07/11/08 |
| 08ST3119 | 04JM194-E1 | Bench Lake | John Muir WA | 1145 | 07/08/08 | 07/11/08 |
| 08ST3120 | 04JM194-E2 | Bench Lake | John Muir WA | 1142 | 07/08/08 | 07/11/08 |
| 08ST3124 | 15JM292-E2 | East Wahoo Lake | John Muir WA | 936 | 07/10/08 | 07/15/08 |
| 08ST3123 | 15JM292-E1 | East Wahoo Lake | John Muir WA | 933 | 07/10/08 | 07/15/08 |
| 08ST3186 | 16EM27-S1 | Karls Lake Shoreline | Emigrant WA | 806 | 07/13/08 | 07/15/08 |
| 08ST3187 | 16EM27-S2 | Karls Lake Shoreline | Emigrant WA | 808 | 07/13/08 | 07/15/08 |
| 08ST3005 | 03DE003-E1 | Waca Lake | Desolation WA | 1008 | 07/15/08 | 07/18/08 |
| 08ST3004 | 03DE003-E2 | Waca Lake Duplicate | Desolation WA | 1012 | 07/15/08 | 07/18/08 |
| 08ST3007 | 03DE003-H1 | Waca Lake | Desolation WA | 1115 | 07/15/08 | 07/18/08 |
| 08ST3006 | 03DE003-H2 | Waca Lake | Desolation WA | 1117 | 07/15/08 | 07/18/08 |
| 08ST3188 | 16EM28-1S | Key Lake | Emigrant WA | 1215 | 07/17/08 | 07/23/08 |
| 08ST3189 | 16EM28-2S | Key Lake Duplicate | Emigrant WA | 1216 | 07/17/08 | 07/23/08 |
| 08ST3190 | 16EM28-FB | Key Lake Field Blank | Emigrant WA | | 07/17/08 | 07/23/08 |
| 08ST3125 | 04AA132-E1 | Little East Marie Lake | Ansel Adams WA | 900 | 07/23/08 | 07/25/08 |
| 08ST3126 | 04AA132-E2 | Little East Marie Lake Duplicate | Ansel Adams WA | 904 | 07/23/08 | 07/29/08 |
| 08ST3049 | 04AA001-01 | Dana Lake | Ansel Adams WA | 1200 | 07/24/08 | 07/29/08 |
| 08ST3050 | 04AA001-02 | Dana Lake Duplicate | Ansel Adams WA | 1210 | 07/24/08 | 07/29/08 |
| 08ST3008 | 03MK14-FB | Moke 14 Field Blank | Mokelumne WA | 1430 | 08/04/08 | 08/07/08 |
| 08ST3009 | 03MK14-S1 | Moke 14 | Mokelumne WA | 1421 | 08/04/08 | 08/07/08 |
| 08ST3010 | 03MK14-S2 | Moke 14 Duplicate | Mokelumne WA | 1426 | 08/04/08 | 08/07/08 |
| 08ST3011 | 03MK19-S1 | Lower Cole Creek Lake | Mokelumne WA | 952 | 08/05/08 | 08/07/08 |
| 08ST3012 | 03MK19-S2 | Lower Cole Creek Lake Dup | Mokelumne WA | 955 | 08/05/08 | 08/07/08 |
| 08ST3160 | 09SW04-FB | Patterson Lake Field Blank | South Warner | | 08/19/08 | 08/21/08 |
| 08ST3161 | 09SW04-E2 | Patterson Lake Duplicate | South Warner | 1125 | 08/19/08 | 08/21/08 |
| 08ST3162 | 09SW04-H1 | Patterson Lake | South Warner | 1115 | 08/19/08 | 08/21/08 |
| 08ST3163 | 09SW04-H2 | Patterson Lake Duplicate | South Warner | 1115 | 08/19/08 | 08/21/08 |
| 08ST3164 | 09SW04-E1 | Patterson Lake | South Warner | 1125 | 08/19/08 | 08/21/08 |
| 08ST3024 | 17HO004-1 | Moat Lake Outlet | Hoover WA | 858 | 09/18/08 | 09/23/08 |

| SAMPLE ID | pH | uE/L ANC | uS/cm Conduct. | mg/l Na | mg/l NH4 | mg/l K | mg/l Mg |
|---|---|---|---|---|---|---|---|
| Bullfrog Lake | 6.190 | 24.3 | 3.80 | 0.397 | 0 | 0.125 | 0.052 |
| Bullfrog Lake | 6.167 | 26.2 | 3.71 | 0.399 | 0 | 0.124 | 0.05 |
| Bullfrog Lake | 6.087 | 23.5 | 3.97 | 0.382 | 0 | 0.134 | 0.05 |
| Bullfrog Lake | 6.067 | 25.4 | 3.83 | 0.398 | 0 | 0.163 | 0.056 |
| Long Lake | 6.170 | 50.3 | 6.17 | 0.542 | 0 | 0.252 | 0.066 |
| Long Lake | 6.218 | 52.4 | 6.43 | 0.548 | 0 | 0.241 | 0.071 |
| Long Lake | 6.360 | 50.1 | 5.98 | 0.525 | 0 | 0.204 | 0.078 |
| Long Lake | 5.631 | 7.4 | 0.98 | 0 | 0.012 | 0 | 0.007 |
| Long Lake | 6.414 | 48.4 | 6.04 | 0.541 | 0 | 0.232 | 0.102 |
| Long Lake | 6.248 | 48.6 | 6.35 | 0.552 | 0 | 0.236 | 0.076 |
| Long Lake | 6.326 | 49.2 | 5.96 | 0.529 | 0 | 0.219 | 0.081 |
| East Chain Lake | 6.533 | 43.3 | 5.20 | 0.455 | 0 | 0.247 | 0.052 |
| East Chain Lake | 6.524 | 43.4 | 5.09 | 0.448 | 0 | 0.204 | 0.056 |
| East Chain Lake | 6.536 | 46.1 | 5.29 | 0.427 | 0 | 0.178 | 0.05 |
| East Chain Lake | 6.516 | 46.3 | 5.28 | 0.463 | 0 | 0.176 | 0.058 |
| Powell Lake (midlake) | 6.079 | 28.1 | 3.93 | 0.371 | 0 | 0.185 | 0.087 |
| Powell Lake (midlake) | 6.104 | 26.3 | 3.86 | 0.344 | 0 | 0.125 | 0.077 |
| Powell Lake (midlake) | 6.092 | 56.0 | 7.11 | 0.436 | 0.151 | 0.202 | 0.119 |
| Powell Lake (midlake) | 6.097 | 57.2 | 7.15 | 0.441 | 0.153 | 0.226 | 0.129 |
| Powell Lake (shoreline) | 6.148 | 24.9 | 3.76 | 0.355 | 0 | 0.134 | 0.067 |
| Powell Lake (shoreline) | 6.156 | 28.4 | 3.75 | 0.378 | 0 | 0.162 | 0.079 |
| Caribou #8 | 6.440 | 26.9 | 4.01 | 0.2 | 0.047 | 0.128 | 0.247 |
| Caribou #8 | 5.713 | 1.0 | 1.02 | 0 | 0.008 | 0 | 0.02 |
| Moat Lake shoreline | 6.593 | 69.4 | 10.81 | 0.539 | 0 | 0.35 | 0.12 |
| Moat Lake shoreline Duplicate | 6.583 | 67.6 | 10.31 | 0.52 | 0 | 0.258 | 0.126 |
| Moat Lake epilimnion | 6.635 | 71.0 | 10.29 | 0.517 | 0 | 0.261 | 0.123 |
| Moat Lake epilimnion Duplicate | 6.648 | 71.5 | 10.04 | 0.507 | 0 | 0.262 | 0.123 |
| Caribou #8 (Surface) | 6.378 | 27.5 | 3.56 | 0.221 | 0 | 0.098 | 0.251 |
| Vermilion Lake | 6.571 | 47.05 | 4.35 | 0.677 | 0 | 0.283 | 0.06 |
| Vermilion Lake | 6.597 | 44.9 | 4.35 | 0.66 | 0 | 0.211 | 0.067 |
| Walton Lake | 6.255 | 21.5 | 3.12 | 0.195 | 0 | 0.112 | 0.052 |
| Hufford Lake | 6.693 | 46.6 | 4.69 | 0.327 | 0 | 0.126 | 0.146 |
| Hufford Lake Field Blank | 5.677 | 0.1 | 0.92 | 0 | 0.019 | 0 | 0.031 |
| Treasure Lake SE | 5.679 | -0.8 | 0.86 | 0.038 | 0.027 | 0.034 | 0.025 |
| Treasure Lake SE | 6.596 | 28.9 | 4.96 | 0.344 | 0 | 0.225 | 0.066 |
| Treasure Lake SE | 6.588 | 33.1 | 4.62 | 0.275 | 0.025 | 0.227 | 0.062 |
| Treasure Lake SE | 6.618 | 32.1 | 4.41 | 0.225 | 0.024 | 0.221 | 0.063 |
| Treasure Lake SE | 6.606 | 35.6 | 4.50 | 0.213 | 0.03 | 0.19 | 0.057 |
| Hufford Lake Duplicate | 6.635 | 43.9 | 4.72 | 0.303 | 0.035 | 0.114 | 0.148 |
| Walton Lake | 6.284 | 17.1 | 3.41 | 0.21 | 0 | 0.101 | 0.058 |
| Cascade Lake | 6.434 | 22.3 | 3.55 | 0.33 | 0 | 0.106 | 0.053 |
| Cascade Lake | 6.449 | 21.9 | 3.52 | 0.322 | 0 | 0.111 | 0.057 |
| Cascade Lake | 6.460 | 21.0 | 3.57 | 0.318 | 0 | 0.112 | 0.058 |
| Cascade Lake | 6.476 | 26.3 | 3.64 | 0.33 | 0 | 0.106 | 0.054 |
| Smith Lake | 6.313 | 13.4 | 3.01 | 0.309 | 0 | 0.098 | 0.055 |
| Smith Lake | 6.317 | 10.8 | 2.92 | 0.315 | 0 | 0.09 | 0.057 |
| Smith Lake | 6.217 | 13.2 | 3.12 | 0.312 | 0 | 0.093 | 0.063 |

| SAMPLE ID | pH | uE/L ANC | uS/cm Conduct. | mg/l Na | mg/l NH4 | mg/l K | mg/l Mg |
|---|---|---|---|---|---|---|---|
| Smith Lake | 6.227 | 17.7 | 3.15 | 0.312 | 0 | 0.102 | 0.056 |
| Bench Lake | 7.055 | 76.5 | 11.00 | 0.592 | 0 | 0.12 | 0.106 |
| Bench Lake | 7.039 | 71.5 | 11.08 | 0.596 | 0 | 0.125 | 0.11 |
| East Wahoo Lake | 6.962 | 76.1 | 7.58 | 0.44 | 0 | 0.199 | 0.072 |
| East Wahoo Lake | 6.968 | 73.3 | 7.66 | 0.458 | 0 | 0.2 | 0.078 |
| Karls Lake Shoreline | 6.064 | 19.2 | 2.98 | 0.253 | 0 | 0.104 | 0.066 |
| Karls Lake Shoreline | 6.068 | 16.6 | 3.00 | 0.234 | 0 | 0.117 | 0.065 |
| Waca Lake | 6.084 | 15.9 | 2.68 | 0.163 | 0.019 | 0.103 | 0.062 |
| Waca Lake Duplicate | 6.202 | 20.7 | 2.58 | 0.14 | 0.019 | 0.092 | 0.053 |
| Waca Lake | 6.041 | 27.1 | 3.14 | 0.147 | 0.026 | 0.095 | 0.053 |
| Waca Lake | 6.054 | 25.7 | 3.13 | 0.154 | 0.031 | 0.113 | 0.059 |
| Key Lake | 6.025 | 17.5 | 2.58 | 0.151 | 0.061 | 0.119 | 0.052 |
| Key Lake Duplicate | 5.993 | 19.4 | 2.59 | 0.15 | 0.063 | 0.109 | 0.053 |
| Key Lake Field Blank | 5.688 | 1.8 | 0.91 | 0 | 0.062 | 0.028 | 0.015 |
| Little East Marie Lake | 6.337 | 22.7 | 4.21 | 0.156 | 0.06 | 0.154 | 0.06 |
| Little East Marie Lake Duplicate | 6.257 | 22.0 | 4.51 | 0.166 | 0.027 | 0.16 | 0.044 |
| Dana Lake | 6.298 | 16.9 | 16.49 | 0.317 | 0.032 | 0.243 | 0.207 |
| Dana Lake Duplicate | 6.306 | 21.5 | 16.61 | 0.34 | 0.034 | 0.285 | 0.224 |
| Moke 14 Field Blank | 5.644 | 3.6 | 0.89 | 0 | 0.013 | 0 | 0 |
| Moke 14 | 5.972 | 12.0 | 3.83 | 0.497 | 0.017 | 0.14 | 0.051 |
| Moke 14 Duplicate | 5.979 | 15.3 | 3.84 | 0.506 | 0.029 | 0.132 | 0.058 |
| Lower Cole Creek Lake | 6.366 | 37.8 | 5.09 | 0.404 | 0.023 | 0.148 | 0.091 |
| Lower Cole Creek Lake Dup | 6.370 | 34.3 | 4.87 | 0.414 | 0.019 | 0.159 | 0.091 |
| Patterson Lake Field Blank | 5.697 | 3.8 | 0.81 | 0.022 | 0.054 | 0.045 | 0.001 |
| Patterson Lake Duplicate | 7.922 | 155.8 | 16.20 | 1.021 | 0 | 0.615 | 0.55 |
| Patterson Lake | 6.775 | 169.2 | 16.97 | 1.032 | 0 | 0.591 | 0.57 |
| Patterson Lake Duplicate | 6.779 | 173.0 | 16.99 | 1.032 | 0 | 0.603 | 0.567 |
| Patterson Lake | 8.013 | 164.8 | 16.48 | 1.001 | 0 | 0.586 | 0.557 |
| Moat Lake Outlet | 6.894 | 65.1 | 10.13 | 0.655 | 0 | 0.374 | 0.08 |

| SAMPLE ID | mg/l Ca | mg/l F | mg/l Cl | mg/l NO3 | mg/l PO4 | mg/l SO4 | ueq/L ANC |
|---|---|---|---|---|---|---|---|
| Bullfrog Lake | 0.249 | 0.0150 | 0.0830 | 0.0000 | 0.0000 | 0.1130 | 3.8 |
| Bullfrog Lake | 0.208 | 0.0120 | 0.0860 | 0.0010 | 0.0000 | 0.1040 | 3.7 |
| Bullfrog Lake | 0.201 | 0.0130 | 0.0820 | 0.0050 | 0.0000 | 0.1110 | 4.0 |
| Bullfrog Lake | 0.206 | 0.0140 | 0.0890 | 0.0030 | 0.0000 | 0.1040 | 3.8 |
| Long Lake | 0.527 | 0.0140 | 0.1040 | 0.0000 | 0.0000 | 0.1360 | 6.2 |
| Long Lake | 0.601 | 0.0170 | 0.1030 | 0.0810 | 0.0000 | 0.1320 | 6.4 |
| Long Lake | 0.526 | 0.0180 | 0.0890 | 0.0620 | 0.0000 | 0.1230 | 6.0 |
| Long Lake | 0.045 | 0.0040 | 0.0020 | 0.0000 | 0.0010 | 0.0400 | 1.0 |
| Long Lake | 0.562 | 0.0100 | 0.0840 | 0.0750 | 0.0010 | 0.1230 | 6.0 |
| Long Lake | 0.636 | 0.0090 | 0.0910 | 0.0780 | 0.0020 | 0.1270 | 6.4 |
| Long Lake | 0.58 | 0.0100 | 0.0940 | 0.0670 | 0.0010 | 0.1300 | 6.0 |
| East Chain Lake | 0.55 | 0.0100 | 0.1220 | 0.0120 | 0.0000 | 0.1250 | 5.2 |
| East Chain Lake | 0.641 | 0.0110 | 0.1090 | 0.0040 | 0.0000 | 0.1190 | 5.1 |
| East Chain Lake | 0.583 | 0.0120 | 0.0730 | 0.0220 | 0.0000 | 0.1290 | 5.3 |
| East Chain Lake | 0.63 | 0.0100 | 0.0820 | 0.0220 | 0.0010 | 0.1180 | 5.3 |
| Powell Lake (midlake) | 0.303 | 0.0130 | 0.0930 | 0.0230 | 0.0050 | 0.1240 | 3.9 |
| Powell Lake (midlake) | 0.296 | 0.0130 | 0.0900 | 0.0220 | 0.0000 | 0.1260 | 3.9 |
| Powell Lake (midlake) | 0.503 | 0.0120 | 0.1090 | 0.0210 | 0.0000 | 0.1240 | 7.1 |
| Powell Lake (midlake) | 0.543 | 0.0130 | 0.1180 | 0.0210 | 0.0000 | 0.1250 | 7.2 |
| Powell Lake (shoreline) | 0.301 | 0.0090 | 0.0970 | 0.0240 | 0.0000 | 0.1210 | 3.8 |
| Powell Lake (shoreline) | 0.294 | 0.0100 | 0.1240 | 0.0210 | 0.0040 | 0.1250 | 3.8 |
| Caribou #8 | 0.203 | 0.0160 | 0.1010 | 0.0240 | 0.0050 | 0.0340 | 4.0 |
| Caribou #8 | 0.096 | 0.0230 | 0.0390 | 0.0320 | 0.0000 | 0.0060 | 1.0 |
| Moat Lake shoreline | 1.271 | 0.0220 | 0.1590 | 0.1120 | 0.0030 | 0.9350 | 10.8 |
| Moat Lake shoreline Duplicate | 1.213 | 0.0120 | 0.0900 | 0.1170 | 0.0010 | 0.9270 | 10.3 |
| Moat Lake epilimnion | 1.314 | 0.0110 | 0.0800 | 0.1130 | 0.0000 | 0.9300 | 10.3 |
| Moat Lake epilimnion Duplicate | 1.244 | 0.0090 | 0.0840 | 0.1250 | 0.0030 | 0.9250 | 10.0 |
| Caribou #8 (Surface) | 0.217 | 0.0100 | 0.0870 | 0.0210 | 0.0000 | 0.0280 | 3.6 |
| Vermilion Lake | 0.337 | 0.0220 | 0.0670 | 0.0280 | 0.0020 | 0.1780 | 4.4 |
| Vermilion Lake | 0.34 | 0.0200 | 0.0560 | 0.0300 | 0.0000 | 0.1760 | 4.4 |
| Walton Lake | 0.419 | 0.0200 | 0.0440 | 0.1370 | 0.0010 | 0.2620 | 3.1 |
| Hufford Lake | 0.523 | 0.0140 | 0.1510 | 0.0230 | 0.0040 | 0.1190 | 4.7 |
| Hufford Lake Field Blank | 0.124 | 0.0150 | 0.0240 | 0.0250 | 0.0000 | 0.0090 | 0.9 |
| Treasure Lake SE | 0.11 | 0.0120 | 0.0260 | 0.0250 | 0.0010 | 0.0080 | 0.9 |
| Treasure Lake SE | 0.677 | 0.0100 | 0.1840 | 0.3740 | 0.0000 | 0.2150 | 5.0 |
| Treasure Lake SE | 0.67 | 0.0100 | 0.1450 | 0.3780 | 0.0000 | 0.2080 | 4.6 |
| Treasure Lake SE | 0.684 | 0.0110 | 0.0900 | 0.3880 | 0.0010 | 0.2050 | 4.4 |
| Treasure Lake SE | 0.665 | 0.0130 | 0.0840 | 0.3790 | 0.0060 | 0.2010 | 4.5 |
| Hufford Lake Duplicate | 0.543 | 0.0250 | 0.1500 | 0.0310 | 0.0010 | 0.1170 | 4.7 |
| Walton Lake | 0.454 | 0.0170 | 0.0460 | 0.1380 | 0.0000 | 0.2660 | 3.4 |
| Cascade Lake | 0.403 | 0.0200 | 0.0440 | 0.0530 | 0.0020 | 0.1710 | 3.6 |
| Cascade Lake | 0.416 | 0.0170 | 0.0470 | 0.0520 | 0.0010 | 0.1670 | 3.5 |
| Cascade Lake | 0.415 | 0.0200 | 0.0470 | 0.0500 | 0.0000 | 0.1710 | 3.6 |
| Cascade Lake | 0.412 | 0.0170 | 0.0440 | 0.0500 | 0.0030 | 0.1730 | 3.6 |
| Smith Lake | 0.237 | 0.0110 | 0.1000 | 0.1410 | 0.0000 | 0.2470 | 3.0 |
| Smith Lake | 0.304 | 0.0150 | 0.1040 | 0.1330 | 0.0000 | 0.2010 | 10.8 |
| Smith Lake | 0.307 | 0.0150 | 0.0910 | 0.0900 | 0.0030 | 0.1600 | 3.1 |

| SAMPLE ID | mg/l Ca | mg/l F | mg/l Cl | mg/l NO3 | mg/l PO4 | mg/l SO4 | ueq/L ANC |
|---|---|---|---|---|---|---|---|
| Smith Lake | 0.291 | 0.0120 | 0.0970 | 0.0940 | 0.0000 | 0.1720 | 3.2 |
| Bench Lake | 1.543 | 0.0160 | 0.0930 | 0.9800 | 0.0000 | 0.7170 | 11.0 |
| Bench Lake | 1.579 | 0.0160 | 0.0950 | 1.0050 | 0.0050 | 0.7180 | 11.1 |
| East Wahoo Lake | 1.172 | 0.0240 | 0.0470 | 0.0280 | 0.0000 | 0.2610 | 7.6 |
| East Wahoo Lake | 1.158 | 0.0200 | 0.0470 | 0.0290 | 0.0010 | 0.2640 | 7.7 |
| Karls Lake Shoreline | 0.309 | 0.0230 | 0.0610 | 0.0550 | 0.0010 | 0.0390 | 3.0 |
| Karls Lake Shoreline | 0.302 | 0.0230 | 0.1090 | 0.0320 | 0.0020 | 0.0460 | 3.0 |
| Waca Lake | 0.327 | 0.0210 | 0.0910 | 0.0390 | 0.0040 | 0.1240 | 2.7 |
| Waca Lake Duplicate | 0.285 | 0.0200 | 0.1100 | 0.1160 | 0.0070 | 0.1190 | 2.6 |
| Waca Lake | 0.311 | 0.0200 | 0.1120 | 0.0490 | 0.0040 | 0.1060 | 3.1 |
| Waca Lake | 0.325 | 0.0210 | 0.1230 | 0.0610 | 0.0000 | 0.1170 | 3.1 |
| Key Lake | 0.21 | 0.0190 | 0.0640 | 0.0300 | 0.0000 | 0.1240 | 2.6 |
| Key Lake Duplicate | 0.214 | 0.0200 | 0.0610 | 0.0350 | 0.0280 | 0.1200 | 2.6 |
| Key Lake Field Blank | 0.077 | 0.0210 | 0.0330 | 0.0410 | 0.0010 | 0.0070 | 0.9 |
| Little East Marie Lake | 0.509 | 0.0190 | 0.0460 | 0.3300 | 0.0000 | 0.5170 | 4.2 |
| Little East Marie Lake Duplicate | 0.514 | 0.0000 | 0.0590 | 0.3350 | 0.0000 | 0.5060 | 4.5 |
| Dana Lake | 2.062 | 0.0210 | 0.0920 | 0.8060 | 0.0010 | 4.7760 | 16.5 |
| Dana Lake Duplicate | 2.164 | 0.0210 | 0.0960 | 0.8010 | 0.0000 | 4.7840 | 16.6 |
| Moke 14 Field Blank | 0.029 | 0.0350 | 0.0070 | 0.0140 | 0.0000 | 0.0100 | 0.9 |
| Moke 14 | 0.158 | 0.0090 | 0.2310 | 0.0120 | 0.0000 | 0.0420 | 3.8 |
| Moke 14 Duplicate | 0.151 | 0.0090 | 0.2300 | 0.0120 | 0.0000 | 0.0440 | 3.8 |
| Lower Cole Creek Lake | 0.424 | 0.0200 | 0.1960 | 0.0130 | 0.0010 | 0.0380 | 5.1 |
| Lower Cole Creek Lake Duplicate | 0.438 | 0.0040 | 0.1990 | 0.0110 | 0.0020 | 0.0440 | 4.9 |
| Patterson Lake Field Blank | 0.04 | 0.0000 | 0.0100 | 0.0000 | 0.0020 | 0.0050 | 0.81 |
| Patterson Lake Duplicate | 1.433 | 0.0190 | 0.1060 | 0.0000 | 0.0000 | 0.0900 | 16.2 |
| Patterson Lake | 1.572 | 0.0180 | 0.0950 | 0.1710 | 0.0000 | 0.1640 | 16.97 |
| Patterson Lake Duplicate | 1.504 | 0.0190 | 0.0940 | 0.1730 | 0.0000 | 0.1700 | 16.99 |
| Patterson Lake | 1.442 | 0.0190 | 0.0990 | 0.0000 | 0.0000 | 0.0980 | 16.48 |
| Moat Lake Outlet | 0.99 | 0.0080 | 0.2680 | 0.0000 | 0.0000 | 0.8510 | 10.13 |

| SAMPLE ID | ueq/L H | ueq/L Ca | ueq/L Mg | ueq/L Na | ueq/L K | ueq/L NH4 | ueq/L F |
|---|---|---|---|---|---|---|---|
| Bullfrog Lake | 0.646 | 12.425 | 4.279 | 17.269 | 3.197 | 0.000 | 0.790 |
| Bullfrog Lake | 0.681 | 10.379 | 4.114 | 17.356 | 3.171 | 0.000 | 0.632 |
| Bullfrog Lake | 0.819 | 10.030 | 4.114 | 16.616 | 3.427 | 0.000 | 0.684 |
| Bullfrog Lake | 0.857 | 10.279 | 4.608 | 17.312 | 4.169 | 0.000 | 0.737 |
| Long Lake | 0.676 | 26.297 | 5.431 | 23.576 | 6.445 | 0.000 | 0.737 |
| Long Lake | 0.605 | 29.990 | 5.842 | 23.837 | 6.164 | 0.000 | 0.895 |
| Long Lake | 0.437 | 26.248 | 6.418 | 22.836 | 5.218 | 0.000 | 0.947 |
| Long Lake | 2.341 | 2.246 | 0.576 | 0.000 | 0.000 | 0.665 | 0.211 |
| Long Lake | 0.385 | 28.044 | 8.393 | 23.532 | 5.934 | 0.000 | 0.526 |
| Long Lake | 0.565 | 31.737 | 6.254 | 24.011 | 6.036 | 0.000 | 0.474 |
| Long Lake | 0.472 | 28.942 | 6.665 | 23.010 | 5.601 | 0.000 | 0.526 |
| East Chain Lake | 0.293 | 27.445 | 4.279 | 19.791 | 6.317 | 0.000 | 0.526 |
| East Chain Lake | 0.300 | 31.986 | 4.608 | 19.487 | 5.218 | 0.000 | 0.579 |
| East Chain Lake | 0.291 | 29.092 | 4.114 | 18.573 | 4.553 | 0.000 | 0.632 |
| East Chain Lake | 0.305 | 31.437 | 4.773 | 20.139 | 4.501 | 0.000 | 0.526 |
| Powell Lake (midlake) | 0.833 | 15.120 | 7.159 | 16.138 | 4.732 | 0.000 | 0.684 |
| Powell Lake (midlake) | 0.787 | 14.770 | 6.336 | 14.963 | 3.197 | 0.000 | 0.684 |
| Powell Lake (midlake) | 0.809 | 25.100 | 9.792 | 18.965 | 5.166 | 8.371 | 0.632 |
| Powell Lake (midlake) | 0.801 | 27.096 | 10.615 | 19.182 | 5.780 | 8.482 | 0.684 |
| Powell Lake (shoreline) | 0.711 | 15.020 | 5.513 | 15.442 | 3.427 | 0.000 | 0.474 |
| Powell Lake (shoreline) | 0.698 | 14.671 | 6.501 | 16.442 | 4.143 | 0.000 | 0.526 |
| Caribou #8 | 0.363 | 10.130 | 20.325 | 8.700 | 3.274 | 2.606 | 0.842 |
| Caribou #8 | 1.937 | 4.790 | 1.646 | 0.000 | 0.000 | 0.444 | 1.211 |
| Moat Lake shoreline | 0.255 | 63.423 | 9.875 | 23.445 | 8.952 | 0.000 | 1.158 |
| Moat Lake shoreline Duplicate | 0.261 | 60.529 | 10.368 | 22.619 | 6.599 | 0.000 | 0.632 |
| Moat Lake epilimnion | 0.232 | 65.569 | 10.121 | 22.488 | 6.675 | 0.000 | 0.579 |
| Moat Lake epilimnion Duplicate | 0.225 | 62.076 | 10.121 | 22.053 | 6.701 | 0.000 | 0.474 |
| Caribou #8 (Surface) | 0.419 | 10.828 | 20.654 | 9.613 | 2.507 | 0.000 | 0.526 |
| Vermilion Lake | 0.269 | 16.816 | 4.937 | 29.448 | 7.238 | 0.000 | 1.158 |
| Vermilion Lake | 0.253 | 16.966 | 5.513 | 28.708 | 5.397 | 0.000 | 1.053 |
| Walton Lake | 0.556 | 20.908 | 4.279 | 8.482 | 2.865 | 0.000 | 1.053 |
| Hufford Lake | 0.203 | 26.098 | 12.014 | 14.224 | 3.223 | 0.000 | 0.737 |
| Hufford Lake Field Blank | 2.103 | 6.188 | 2.551 | 0.000 | 0.000 | 1.053 | 0.790 |
| Treasure Lake SE | 2.093 | 5.489 | 2.057 | 1.653 | 0.870 | 1.497 | 0.632 |
| Treasure Lake SE | 0.253 | 33.782 | 5.431 | 14.963 | 5.755 | 0.000 | 0.526 |
| Treasure Lake SE | 0.258 | 33.433 | 5.102 | 11.962 | 5.806 | 1.386 | 0.526 |
| Treasure Lake SE | 0.241 | 34.132 | 5.184 | 9.787 | 5.652 | 1.331 | 0.579 |
| Treasure Lake SE | 0.248 | 33.184 | 4.690 | 9.265 | 4.860 | 1.663 | 0.684 |
| Hufford Lake Duplicate | 0.232 | 27.096 | 12.179 | 13.180 | 2.916 | 1.940 | 1.316 |
| Walton Lake | 0.520 | 22.655 | 4.773 | 9.134 | 2.583 | 0.000 | 0.895 |
| Cascade Lake | 0.368 | 20.110 | 4.361 | 14.354 | 2.711 | 0.000 | 1.053 |
| Cascade Lake | 0.356 | 20.758 | 4.690 | 14.006 | 2.839 | 0.000 | 0.895 |
| Cascade Lake | 0.346 | 20.709 | 4.773 | 13.832 | 2.865 | 0.000 | 1.053 |
| Cascade Lake | 0.334 | 20.559 | 4.444 | 14.354 | 2.711 | 0.000 | 0.895 |
| Smith Lake | 0.486 | 11.826 | 4.526 | 13.441 | 2.507 | 0.000 | 0.579 |
| Smith Lake | 0.482 | 15.170 | 4.690 | 13.702 | 2.302 | 0.000 | 0.790 |
| Smith Lake | 0.607 | 15.319 | 5.184 | 13.571 | 2.379 | 0.000 | 0.790 |

| SAMPLE ID | ueq/L H | ueq/L Ca | ueq/L Mg | ueq/L Na | ueq/L K | ueq/L NH4 | ueq/L F |
|---|---|---|---|---|---|---|---|
| Smith Lake | 0.593 | 14.521 | 4.608 | 13.571 | 2.609 | 0.000 | 0.632 |
| Bench Lake | 0.088 | 76.996 | 8.722 | 25.751 | 3.069 | 0.000 | 0.842 |
| Bench Lake | 0.091 | 78.792 | 9.052 | 25.925 | 3.197 | 0.000 | 0.842 |
| East Wahoo Lake | 0.109 | 58.483 | 5.925 | 19.139 | 5.090 | 0.000 | 1.263 |
| East Wahoo Lake | 0.108 | 57.784 | 6.418 | 19.922 | 5.115 | 0.000 | 1.053 |
| Karls Lake Shoreline | 0.864 | 15.419 | 5.431 | 11.005 | 2.660 | 0.000 | 1.211 |
| Karls Lake Shoreline | 0.855 | 15.070 | 5.349 | 10.178 | 2.992 | 0.000 | 1.211 |
| Waca Lake | 0.825 | 16.317 | 5.102 | 7.090 | 2.634 | 1.053 | 1.105 |
| Waca Lake Duplicate | 0.628 | 14.222 | 4.361 | 6.090 | 2.353 | 1.053 | 1.053 |
| Waca Lake | 0.909 | 15.519 | 4.361 | 6.394 | 2.430 | 1.441 | 1.053 |
| Waca Lake | 0.884 | 16.218 | 4.855 | 6.699 | 2.890 | 1.719 | 1.105 |
| Key Lake | 0.945 | 10.479 | 4.279 | 6.568 | 3.044 | 3.382 | 1.000 |
| Key Lake Duplicate | 1.016 | 10.679 | 4.361 | 6.525 | 2.788 | 3.493 | 1.053 |
| Key Lake Field Blank | 2.052 | 3.842 | 1.234 | 0.000 | 0.716 | 3.437 | 1.105 |
| Little East Marie Lake | 0.460 | 25.399 | 4.937 | 6.786 | 3.939 | 3.326 | 1.000 |
| Little East Marie Lake Duplicate | 0.553 | 25.649 | 3.621 | 7.221 | 4.092 | 1.497 | 0.000 |
| Dana Lake | 0.504 | 102.894 | 17.034 | 13.789 | 6.215 | 1.774 | 1.105 |
| Dana Lake Duplicate | 0.494 | 107.984 | 18.432 | 14.789 | 7.289 | 1.885 | 1.105 |
| Moke 14 Field Blank | 2.270 | 1.447 | 0.000 | 0.000 | 0.000 | 0.721 | 1.842 |
| Moke 14 | 1.066 | 7.884 | 4.197 | 21.618 | 3.581 | 0.942 | 0.474 |
| Moke 14 Duplicate | 1.051 | 7.535 | 4.773 | 22.010 | 3.376 | 1.608 | 0.474 |
| Lower Cole Creek Lake | 0.430 | 21.158 | 7.488 | 17.573 | 3.785 | 1.275 | 1.053 |
| Lower Cole Creek Lake Duplicate | 0.427 | 21.856 | 7.488 | 18.008 | 4.067 | 1.053 | 0.211 |
| Patterson Lake Field Blank | 2.010018 | 1.996 | 0.082 | 0.957 | 1.151 | 2.994 | 0.000 |
| Patterson Lake Duplicate | 0.011976 | 71.507 | 45.258 | 44.411 | 15.730 | 0.000 | 1.000 |
| Patterson Lake | 0.16788 | 78.443 | 46.904 | 44.890 | 15.116 | 0.000 | 0.947 |
| Patterson Lake Duplicate | 0.166265 | 75.050 | 46.657 | 44.890 | 15.423 | 0.000 | 1.000 |
| Patterson Lake | 0.009701 | 71.956 | 45.834 | 43.541 | 14.988 | 0.000 | 1.000 |
| Moat Lake Outlet | 0.127761 | 49.401 | 6.583 | 28.491 | 9.566 | 0.000 | 0.421 |

| SAMPLE ID | ueq/L CL | ueq/L NO3 | ueq/L SO4 | ueq/L [ANC] | SUM ANIONS | SUM CATIONS | TOTAL ION | %ION DIFF |
|---|---|---|---|---|---|---|---|---|
| Bullfrog Lake | 2.34 | 0.00 | 2.35 | 24.27 | 29.76 | 37.82 | 67.57 | -11.93 |
| Bullfrog Lake | 2.43 | 0.02 | 2.17 | 26.20 | 31.44 | 35.70 | 67.14 | -6.36 |
| Bullfrog Lake | 2.31 | 0.08 | 2.31 | 23.54 | 28.93 | 35.01 | 63.94 | -9.51 |
| Bullfrog Lake | 2.51 | 0.05 | 2.17 | 25.45 | 30.91 | 37.23 | 68.13 | -9.27 |
| Long Lake | 2.93 | 0.00 | 2.83 | 50.30 | 56.80 | 62.43 | 119.23 | -4.72 |
| Long Lake | 2.91 | 1.31 | 2.75 | 52.35 | 60.21 | 66.44 | 126.65 | -4.92 |
| Long Lake | 2.51 | 1.00 | 2.56 | 50.08 | 57.10 | 61.16 | 118.25 | -3.43 |
| Long Lake | 0.06 | 0.00 | 0.83 | 7.44 | 8.54 | 5.83 | 14.36 | 18.85 |
| Long Lake | 2.37 | 1.21 | 2.56 | 48.38 | 55.04 | 66.29 | 121.33 | -9.27 |
| Long Lake | 2.57 | 1.26 | 2.64 | 48.64 | 55.58 | 68.60 | 124.18 | -10.48 |
| Long Lake | 2.65 | 1.08 | 2.71 | 49.24 | 56.20 | 64.69 | 120.89 | -7.02 |
| East Chain Lake | 3.44 | 0.19 | 2.60 | 43.26 | 50.02 | 58.13 | 108.15 | -7.49 |
| East Chain Lake | 3.07 | 0.06 | 2.48 | 43.37 | 49.56 | 61.60 | 111.16 | -10.83 |
| East Chain Lake | 2.06 | 0.35 | 2.69 | 46.10 | 51.83 | 56.62 | 108.45 | -4.42 |
| East Chain Lake | 2.31 | 0.35 | 2.46 | 46.27 | 51.92 | 61.16 | 113.07 | -8.17 |
| Powell Lake (midlake) | 2.62 | 0.37 | 2.58 | 28.08 | 34.34 | 43.98 | 78.32 | -12.31 |
| Powell Lake (midlake) | 2.54 | 0.35 | 2.62 | 26.34 | 32.54 | 40.05 | 72.59 | -10.35 |
| Powell Lake (midlake) | 3.07 | 0.34 | 2.58 | 56.03 | 62.65 | 68.20 | 130.86 | -4.24 |
| Powell Lake (midlake) | 3.33 | 0.34 | 2.60 | 57.16 | 64.11 | 71.96 | 136.07 | -5.76 |
| Powell Lake (shoreline) | 2.74 | 0.39 | 2.52 | 24.91 | 31.02 | 40.11 | 71.14 | -12.78 |
| Powell Lake (shoreline) | 3.50 | 0.34 | 2.60 | 28.39 | 35.35 | 42.45 | 77.81 | -9.13 |
| Caribou #8 | 2.85 | 0.39 | 0.71 | 26.85 | 31.64 | 45.40 | 77.04 | -17.86 |
| Caribou #8 | 1.10 | 0.52 | 0.12 | 1.04 | 4.00 | 8.82 | 12.81 | -37.62 |
| Moat Lake shoreline | 4.48 | 1.81 | 19.47 | 69.44 | 96.36 | 105.95 | 202.31 | -4.74 |
| Moat Lake shoreline Duplicate | 2.54 | 1.89 | 19.30 | 67.62 | 91.98 | 100.38 | 192.35 | -4.37 |
| Moat Lake epilimnion | 2.26 | 1.82 | 19.36 | 70.95 | 94.97 | 105.09 | 200.06 | -5.05 |
| Moat Lake epilimnion Duplicate | 2.37 | 2.02 | 19.26 | 71.55 | 95.67 | 101.18 | 196.84 | -2.80 |
| Caribou #8 (Surface) | 2.45 | 0.34 | 0.58 | 27.53 | 31.43 | 44.02 | 75.46 | -16.68 |
| Vermilion Lake | 1.89 | 0.45 | 3.71 | 47.05 | 54.25 | 58.71 | 112.96 | -3.94 |
| Vermilion Lake | 1.58 | 0.48 | 3.66 | 44.93 | 51.71 | 56.84 | 108.55 | -4.72 |
| Walton Lake | 1.24 | 2.21 | 5.46 | 21.48 | 31.44 | 37.09 | 68.53 | -8.25 |
| Hufford Lake | 4.26 | 0.37 | 2.48 | 46.58 | 54.42 | 55.76 | 110.18 | -1.21 |
| Hufford Lake Field Blank | 0.68 | 0.40 | 0.19 | 0.12 | 2.17 | 11.89 | 14.07 | -69.08 |
| Treasure Lake SE | 0.73 | 0.40 | 0.17 | -0.83 | 1.10 | 13.66 | 14.76 | -85.07 |
| Treasure Lake SE | 5.19 | 6.03 | 4.48 | 28.90 | 45.12 | 60.18 | 105.30 | -14.31 |
| Treasure Lake SE | 4.09 | 6.10 | 4.33 | 33.07 | 48.11 | 57.95 | 106.06 | -9.27 |
| Treasure Lake SE | 2.54 | 6.26 | 4.27 | 32.14 | 45.79 | 56.33 | 102.11 | -10.32 |
| Treasure Lake SE | 2.37 | 6.11 | 4.18 | 35.60 | 48.95 | 53.91 | 102.86 | -4.82 |
| Hufford Lake Duplicate | 4.23 | 0.50 | 2.44 | 43.87 | 52.35 | 57.54 | 109.89 | -4.72 |
| Walton Lake | 1.30 | 2.23 | 5.54 | 17.05 | 27.01 | 39.66 | 66.67 | -18.98 |
| Cascade Lake | 1.24 | 0.85 | 3.56 | 22.30 | 29.01 | 41.90 | 70.91 | -18.18 |
| Cascade Lake | 1.33 | 0.84 | 3.48 | 21.93 | 28.47 | 42.65 | 71.12 | -19.94 |
| Cascade Lake | 1.33 | 0.81 | 3.56 | 21.01 | 27.76 | 42.52 | 70.28 | -21.01 |
| Cascade Lake | 1.24 | 0.81 | 3.60 | 26.31 | 32.85 | 42.40 | 75.25 | -12.69 |
| Smith Lake | 2.82 | 2.27 | 5.14 | 13.44 | 24.25 | 32.79 | 57.04 | -14.96 |
| Smith Lake | 2.93 | 2.14 | 4.18 | 10.80 | 20.85 | 36.35 | 57.20 | -27.09 |
| Smith Lake | 2.57 | 1.45 | 3.33 | 13.25 | 21.39 | 37.06 | 58.45 | -26.82 |

| SAMPLE ID | ueq/L CL | ueq/L NO3 | ueq/L SO4 | ueq/L [ANC] | SUM ANIONS | SUM CATIONS | TOTAL ION | %ION DIFF |
|---|---|---|---|---|---|---|---|---|
| Smith Lake | 2.74 | 1.52 | 3.58 | 17.75 | 26.21 | 35.90 | 62.11 | -15.60 |
| Bench Lake | 2.62 | 15.81 | 14.93 | 76.45 | 110.65 | 114.63 | 225.28 | -1.77 |
| Bench Lake | 2.68 | 16.21 | 14.95 | 71.47 | 106.15 | 117.06 | 223.21 | -4.89 |
| East Wahoo Lake | 1.33 | 0.45 | 5.43 | 76.10 | 84.57 | 88.75 | 173.32 | -2.41 |
| East Wahoo Lake | 1.33 | 0.47 | 5.50 | 73.33 | 81.67 | 89.35 | 171.02 | -4.49 |
| Karls Lake Shoreline | 1.72 | 0.89 | 0.81 | 19.16 | 23.79 | 35.38 | 59.17 | -19.58 |
| Karls Lake Shoreline | 3.07 | 0.52 | 0.96 | 16.57 | 22.33 | 34.44 | 56.77 | -21.34 |
| Waca Lake | 2.57 | 0.63 | 2.58 | 15.87 | 22.75 | 33.02 | 55.77 | -18.42 |
| Waca Lake Duplicate | 3.10 | 1.87 | 2.48 | 20.69 | 29.20 | 28.71 | 57.90 | 0.85 |
| Waca Lake | 3.16 | 0.79 | 2.21 | 27.06 | 34.27 | 31.05 | 65.32 | 4.92 |
| Waca Lake | 3.47 | 0.98 | 2.44 | 25.70 | 33.70 | 33.26 | 66.96 | 0.65 |
| Key Lake | 1.81 | 0.48 | 2.58 | 17.53 | 23.40 | 28.70 | 52.09 | -10.17 |
| Key Lake Duplicate | 1.72 | 0.56 | 2.50 | 19.37 | 25.20 | 28.86 | 54.06 | -6.76 |
| Key Lake Field Blank | 0.93 | 0.66 | 0.15 | 1.78 | 4.63 | 11.28 | 15.91 | -41.83 |
| Little East Marie Lake | 1.30 | 5.32 | 10.76 | 22.71 | 41.09 | 44.85 | 85.94 | -4.37 |
| Little East Marie Lake Duplicate | 1.66 | 5.40 | 10.54 | 22.00 | 39.60 | 42.63 | 82.23 | -3.69 |
| Dana Lake | 2.59 | 13.00 | 99.44 | 16.89 | 133.03 | 142.21 | 275.23 | -3.34 |
| Dana Lake Duplicate | 2.71 | 12.92 | 99.61 | 21.47 | 137.81 | 150.87 | 288.68 | -4.53 |
| Moke 14 Field Blank | 0.20 | 0.23 | 0.21 | 3.59 | 6.06 | 4.44 | 10.50 | 15.46 |
| Moke 14 | 6.52 | 0.19 | 0.87 | 12.01 | 20.07 | 39.29 | 59.36 | -32.38 |
| Moke 14 Duplicate | 6.49 | 0.19 | 0.92 | 15.29 | 23.36 | 40.35 | 63.71 | -26.67 |
| Lower Cole Creek Lake | 5.53 | 0.21 | 0.79 | 37.85 | 45.43 | 51.71 | 97.14 | -6.46 |
| Lower Cole Creek Lake Duplicate | 5.61 | 0.18 | 0.92 | 34.32 | 41.23 | 52.90 | 94.13 | -12.39 |
| Patterson Lake Field Blank | 0.28 | 0.00 | 0.10 | 3.81 | 4.19 | 9.19 | 13.38 | -37.32 |
| Patterson Lake Duplicate | 2.99 | 0.00 | 1.87 | 155.85 | 161.71 | 176.92 | 338.63 | -4.49 |
| Patterson Lake | 2.68 | 2.76 | 3.41 | 169.20 | 179.00 | 185.52 | 364.52 | -1.79 |
| Patterson Lake Duplicate | 2.65 | 2.79 | 3.54 | 173.03 | 183.01 | 182.19 | 365.20 | 0.23 |
| Patterson Lake | 2.79 | 0.00 | 2.04 | 164.78 | 170.62 | 176.33 | 346.95 | -1.65 |
| Moat Lake Outlet | 7.56 | 0.00 | 17.72 | 65.10 | 90.79 | 94.17 | 184.96 | -1.82 |

| SAMPLE ID | SUM BASES | SUM ACIDS | DIFF= ALK | ANC | FLAG %ION | % COND DIFF | FLAG % COND | THEOR. COND |
|---|---|---|---|---|---|---|---|---|
| Bullfrog Lake | 37.17 | 4.69 | 32.48 | 24.27 | OK | -6.60 | OK | 3.55 |
| Bullfrog Lake | 35.02 | 4.61 | 30.41 | 26.20 | OK | -4.90 | OK | 3.53 |
| Bullfrog Lake | 34.19 | 4.70 | 29.48 | 23.54 | OK | -13.57 | OK | 3.43 |
| Bullfrog Lake | 36.37 | 4.72 | 31.64 | 25.45 | OK | -4.61 | OK | 3.65 |
| Long Lake | 61.75 | 5.77 | 55.98 | 50.30 | OK | -1.28 | OK | 6.09 |
| Long Lake | 65.83 | 6.96 | 58.87 | 52.35 | OK | 0.28 | OK | 6.45 |
| Long Lake | 60.72 | 6.07 | 54.65 | 50.08 | OK | -0.69 | OK | 5.94 |
| Long Lake | 2.82 | 0.89 | 1.93 | 7.44 | OK | 42.87 | OK | 1.40 |
| Long Lake | 65.90 | 6.14 | 59.76 | 48.38 | OK | 1.36 | OK | 6.12 |
| Long Lake | 68.04 | 6.47 | 61.57 | 48.64 | OK | -0.09 | OK | 6.34 |
| Long Lake | 64.22 | 6.44 | 57.78 | 49.24 | OK | 2.84 | OK | 6.13 |
| East Chain Lake | 57.83 | 6.24 | 51.60 | 43.26 | OK | 5.73 | OK | 5.50 |
| East Chain Lake | 61.30 | 5.62 | 55.68 | 43.37 | OK | 10.34 | OK | 5.62 |
| East Chain Lake | 56.33 | 5.10 | 51.23 | 46.10 | OK | 2.56 | OK | 5.43 |
| East Chain Lake | 60.85 | 5.12 | 55.73 | 46.27 | OK | 7.32 | OK | 5.67 |
| Powell Lake (midlake) | 43.15 | 5.58 | 37.57 | 28.08 | OK | 6.24 | OK | 4.18 |
| Powell Lake (midlake) | 39.27 | 5.52 | 33.75 | 26.34 | OK | -0.15 | OK | 3.85 |
| Powell Lake (midlake) | 59.02 | 5.99 | 53.03 | 56.03 | OK | -3.62 | OK | 6.85 |
| Powell Lake (midlake) | 62.67 | 6.27 | 56.40 | 57.16 | OK | -0.35 | OK | 7.12 |
| Powell Lake (shoreline) | 39.40 | 5.64 | 33.76 | 24.91 | OK | 0.79 | OK | 3.79 |
| Powell Lake (shoreline) | 41.76 | 6.44 | 35.32 | 28.39 | OK | 10.01 | OK | 4.13 |
| Caribou #8 | 42.43 | 3.94 | 38.48 | 26.85 | OK | -2.19 | OK | 3.92 |
| Caribou #8 | 6.44 | 1.74 | 4.70 | 1.04 | OK | 18.90 | OK | 1.21 |
| Moat Lake shoreline | 105.69 | 25.76 | 79.94 | 69.44 | OK | -2.66 | OK | 10.52 |
| Moat Lake shoreline Duplicate | 100.11 | 23.73 | 76.39 | 67.62 | OK | -3.45 | OK | 9.95 |
| Moat Lake epilimnion | 104.85 | 23.44 | 81.41 | 70.95 | OK | 0.26 | OK | 10.32 |
| Moat Lake epilimnion Duplicate | 100.95 | 23.64 | 77.31 | 71.55 | OK | 1.15 | OK | 10.16 |
| Caribou #8 (Surface) | 43.60 | 3.38 | 40.23 | 27.53 | OK | 6.07 | OK | 3.78 |
| Vermilion Lake | 58.44 | 6.05 | 52.39 | 47.05 | OK | 29.91 | OK | 5.65 |
| Vermilion Lake | 56.58 | 5.73 | 50.86 | 44.93 | OK | 24.02 | OK | 5.40 |
| Walton Lake | 36.53 | 8.91 | 27.63 | 21.48 | OK | 18.06 | OK | 3.68 |
| Hufford Lake | 55.56 | 7.11 | 48.45 | 46.58 | OK | 16.69 | OK | 5.47 |
| Hufford Lake Field Blank | 8.74 | 1.27 | 7.47 | 0.12 | Check | 47.25 | OK | 1.35 |
| Treasure Lake SE | 10.07 | 1.30 | 8.77 | -0.83 | Check | 66.26 | Check | 1.43 |
| Treasure Lake SE | 59.93 | 15.70 | 44.23 | 28.90 | OK | 14.15 | OK | 5.66 |
| Treasure Lake SE | 56.30 | 14.52 | 41.79 | 33.07 | OK | 23.01 | OK | 5.68 |
| Treasure Lake SE | 54.76 | 13.06 | 41.69 | 32.14 | OK | 23.47 | OK | 5.45 |
| Treasure Lake SE | 52.00 | 12.67 | 39.33 | 35.60 | OK | 20.85 | OK | 5.44 |
| Hufford Lake Duplicate | 55.37 | 7.17 | 48.20 | 43.87 | OK | 16.53 | OK | 5.50 |
| Walton Lake | 39.15 | 9.06 | 30.08 | 17.05 | OK | 6.00 | OK | 3.61 |
| Cascade Lake | 41.54 | 5.66 | 35.88 | 22.30 | OK | 3.02 | OK | 3.66 |
| Cascade Lake | 42.29 | 5.64 | 36.65 | 21.93 | OK | 4.47 | OK | 3.68 |
| Cascade Lake | 42.18 | 5.69 | 36.49 | 21.01 | OK | 1.75 | OK | 3.63 |
| Cascade Lake | 42.07 | 5.65 | 36.42 | 26.31 | OK | 5.68 | OK | 3.85 |
| Smith Lake | 32.30 | 10.24 | 22.06 | 13.44 | OK | 5.21 | OK | 3.17 |
| Smith Lake | 35.86 | 9.26 | 26.60 | 10.80 | OK | 8.26 | OK | 3.16 |
| Smith Lake | 36.45 | 7.35 | 29.10 | 13.25 | OK | 2.62 | OK | 3.20 |

| SAMPLE ID | SUM BASES | SUM ACIDS | DIFF= ALK | ANC | FLAG %ION | % COND DIFF | FLAG % COND | THEOR. COND |
|---|---|---|---|---|---|---|---|---|
| Smith Lake | 35.31 | 7.83 | 27.48 | 17.75 | OK | 7.19 | OK | 3.38 |
| Bench Lake | 114.54 | 33.36 | 81.18 | 76.45 | OK | 6.20 | OK | 11.68 |
| Bench Lake | 116.97 | 33.84 | 83.13 | 71.47 | OK | 4.94 | OK | 11.63 |
| East Wahoo Lake | 88.64 | 7.21 | 81.42 | 76.10 | OK | 12.08 | OK | 8.50 |
| East Wahoo Lake | 89.24 | 7.29 | 81.95 | 73.33 | OK | 9.75 | OK | 8.41 |
| Karls Lake Shoreline | 34.51 | 3.42 | 31.10 | 19.16 | OK | 6.58 | OK | 3.18 |
| Karls Lake Shoreline | 33.59 | 4.55 | 29.04 | 16.57 | OK | 3.58 | OK | 3.11 |
| Waca Lake | 31.14 | 5.78 | 25.37 | 15.87 | OK | 15.90 | OK | 3.11 |
| Waca Lake Duplicate | 27.03 | 7.45 | 19.57 | 20.69 | OK | 22.49 | OK | 3.16 |
| Waca Lake | 28.70 | 6.16 | 22.55 | 27.06 | OK | 13.32 | OK | 3.56 |
| Waca Lake | 30.66 | 6.89 | 23.77 | 25.70 | OK | 17.32 | OK | 3.67 |
| Key Lake | 24.37 | 4.87 | 19.50 | 17.53 | OK | 15.79 | OK | 2.99 |
| Key Lake Duplicate | 24.35 | 4.78 | 19.57 | 19.37 | OK | 19.23 | OK | 3.09 |
| Key Lake Field Blank | 5.79 | 1.74 | 4.05 | 1.78 | OK | 63.83 | Check | 1.49 |
| Little East Marie Lake | 41.06 | 17.38 | 23.68 | 22.71 | OK | 14.51 | OK | 4.82 |
| Little East Marie Lake Duplicate | 40.58 | 17.60 | 22.98 | 22.00 | OK | 3.95 | OK | 4.69 |
| Dana Lake | 139.93 | 115.03 | 24.90 | 16.89 | OK | 0.23 | OK | 16.53 |
| Dana Lake Duplicate | 148.49 | 115.23 | 33.26 | 21.47 | OK | 3.58 | OK | 17.20 |
| Moke 14 Field Blank | 1.45 | 0.63 | 0.82 | 3.59 | OK | 26.57 | OK | 1.13 |
| Moke 14 | 37.28 | 7.58 | 29.70 | 12.01 | Check | -9.70 | OK | 3.46 |
| Moke 14 Duplicate | 37.69 | 7.60 | 30.10 | 15.29 | OK | -4.71 | OK | 3.66 |
| Lower Cole Creek Lake | 50.00 | 6.53 | 43.47 | 37.85 | OK | -2.39 | OK | 4.97 |
| Lower Cole Creek Lake Duplicate | 51.42 | 6.71 | 44.71 | 34.32 | OK | 0.35 | OK | 4.89 |
| Patterson Lake Field Blank | 4.19 | 0.39 | 3.80 | 3.81 | OK | 67.74 | Check | 1.36 |
| Patterson Lake Duplicate | 176.91 | 4.86 | 172.04 | 155.85 | OK | 0.56 | OK | 16.29 |
| Patterson Lake | 185.35 | 8.85 | 176.50 | 169.20 | OK | 3.91 | OK | 17.63 |
| Patterson Lake Duplicate | 182.02 | 8.98 | 173.04 | 173.03 | OK | 3.85 | OK | 17.64 |
| Patterson Lake | 176.32 | 4.83 | 171.49 | 164.78 | OK | 0.91 | OK | 16.63 |
| Moat Lake Outlet | 94.04 | 25.28 | 68.76 | 65.10 | OK | -4.52 | OK | 9.67 |